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A cohort time-series Von Bertalanffy growth model for Northern cod (*Gadus morhua*), and estimation of the age of tagged cod

N. Cadigan and C. Konrad

Centre for Fisheries Ecosystem Research
Fisheries and Marine Institute - Memorial University of Newfoundland
PO Box 4920
St. John's, NL A1C 5R3

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ABSTRACT

A Von Bertalanffy growth model is presented to estimate length-at-age for Northern cod (*Gadus morhua*) during 1978-2012 and ages 1-12. Our objective is to use these estimates of size-at-age to estimate the age of tagged fish when they were released, using their length-at-release, quarter of year, and location (i.e. Northwest Atlantic Fisheries Organization [NAFO] Division). Model parameters are estimated using the Department of Fisheries and Oceans (DFO) autumn RV bottom trawl survey mean lengths-at-age in NAFO Divisions 2J, 3K, and 3L during 1978-2012. The model is applied by cohort and NAFO Division but the model is formulated in a mixed-effects framework with fixed parameters for all cohorts and random auto-correlated cohort interactions. The growth model estimates of the age of tagged fish are validated with a small subsample of tagged fish whose ages were estimated at capture using otoliths.

Modèle de croissance de Von Bertalanffy d'une série chronologique de la cohorte de morues du Nord (*Gadus morhua*) et estimation de l'âge des morues marquées

RÉSUMÉ

Un modèle de croissance de Von Bertalanffy est présenté pour estimer la longueur selon l'âge de la morue du Nord (*Gadus morhua*) de 1978 à 2012 et de 1 à 12 ans. Notre objectif consiste à utiliser ces estimations de la taille selon l'âge pour estimer l'âge des poissons marqués à leur remise à l'eau, en utilisant la longueur à la remise à l'eau, du trimestre de l'exercice et de l'emplacement (c.-à-d. la division de l'Organisation des pêches de l'Atlantique Nord-Ouest [OPANO]). Les paramètres du modèle sont estimés à l'aide des longueurs moyennes selon l'âge obtenues par un relevé au chalut de fond effectué à l'automne sur un navire scientifique de Pêches et Océans Canada dans les divisions 2J, 3K, et 3L de l'OPANO de 1978 à 2012. Ce modèle est appliqué par cohorte et par division de l'OPANO, mais le modèle est formulé selon un cadre d'effets mixtes avec des paramètres fixes pour toutes les cohortes et des interactions de cohorte auto-corrélées aléatoire. Les estimations du modèle de croissance de l'âge des poissons marqués sont validées au moyen d'un petit sous-échantillon de poissons marqués dont les âges ont été estimés par les otolithes lors de leur capture.

INTRODUCTION

A fundamental input into stock assessment is information on growth rates, which in this paper refers to changes in length with age, as opposed to weight. Annual estimates of the distribution of ages in a stock conditional on fish size are often used to convert length-disaggregated estimates of catch from commercial fisheries or surveys into age-disaggregated estimates. Growth models are also used in short-term stock projections or longer-term projections that may be used to set fisheries management reference points.

In this paper our focus is to estimate the age of a tagged fish given its length-at-release. This will assist us in incorporating tagging data into the age-structured assessment model for Northern cod outlined in Cadigan (2015). Age cannot be determined at the time of tagging and it is usually not possible to determine the age at capture because fishermen only report the capture and they usually do not return the fish for age determination.

We use length and age information from the Fisheries and Oceans (DFO) autumn bottom trawl Research Vessel (RV) survey to estimate the age of a tagged fish. However, the survey growth rate information is often noisy, especially for those older aged fish that are rarely caught in the survey. This is our motivation to pursue a model-based approach to reduce this variability and infer sizes at some ages not caught in the surveys. We investigate the commonly used Von Bertalanffy (VonB) growth model for the length of a fish as a function of its age. We estimate this model from survey growth data and use the model to estimate length at age (L@A) and to estimate the age of a tagged fish given the year and season (i.e. quarter) it was tagged and information on the location it was caught for tagging. Growth rates for Northern cod may vary spatially, with smaller sized cod in the northern stock area (i.e. NAFO Division 2J) compared to the southern area (3L). In addition, the size of a cod in the spring may be considerably less than in the fall, especially for younger cod.

The spatial differences in L@A are evident in the survey data (see Fig. 1). For example, the length of an age six cod in 3L tends to be greater than in 3K, and cod in 3K tend to be larger than in 2J. However, the reverse is true for age one and this is a feature that needs to be accounted for in our growth model. Growth rates have also changed over time, as evidence by the decline in L@A during the 1980s to the early 1990s when this stock collapsed (DFO 2015). However, L@A seems to have improved more recently although the recent estimates are more variable, presumably because of the lower numbers of fish caught and sampled for ages, especially for larger fish. This variability is even more evident in Fig. 2 for ages 7-12 cod, but the decline in L@A during 1980s to the early 1990s is still evident. Nonetheless, the growth data are fairly consistent in that the average L@A rarely declines for a cohort (Fig. 3). This figure also demonstrates the larger sizes of cod in 3L compared to 2J, although it is interesting that there is little evidence of this pattern for recent cohorts (i.e. since 1990).

In this paper we develop a time-series VonB growth model to estimate the L@A of Northern cod from the various sizes that have been tagged and at the various times of the year and locations that tagging has occurred. The model is designed to account for the features we identified in the exploratory data analyses above. There have been a small number of fish tagged and recaptured, and the otoliths provided to DFO for aging. We compare the ages estimated via the VonB model with the ages estimated from otoliths (i.e. measured ages) to evaluate the efficacy of our approach.

METHODS

VON BERTALANFFY MODEL AND ESTIMATION

The Von Bertalanffy (VonB) model for length at age *a*, denoted as *l(a)*, is

(1) $$l(a) = L_\infty - L_\infty(1-\rho_o)exp(-ka)$$

where L_∞ is the asymptotic length as $a \to \infty$, k is a growth rate parameter, and $\rho_o = l(0)/L_\infty$ is the size at birth relative to the maximum size. The VonB model is derived from the differential equation

(2) $$\partial l(a)/\partial a = k\{L_\infty - l(a)\}$$

The growth rate at birth (i.e. slope at the origin) is $kL_\infty(1-\rho_o) \approx kL_\infty$ and $\partial l(a)/\partial a$ declines to zero as age increases.

The observations are a time-series of average L@A from the DFO autumn bottom-trawl trawl surveys, which we denote as L_{oay}. We fit Eqn. (1) to the L_{oay} for each cohort and NAFO Division with ρ_o assumed to be a constant parameter for all cohorts, but different in each Division. The L_∞ and k parameters are estimated for each cohort and NAFO Division, but not freely. They are assumed to be random effects that are more similar for adjacent cohorts. We model this dependency using random walks for both $L_{c\infty}$ and k_c in each Division, where *c* indicates cohort. Our approach is similar to the maturity model in Cadigan, Morgan, and Brattey (2013), where the logistic regression parameters for cohort maturity were auto-correlated across cohorts. We fit average L@A data so the growth model parameters represent population average growth for cohorts.

The L_{oay} are assumed to the lognormally distributed with means given by Eqn. (1), conditional on the $L_{c\infty}$ and k_c random effects for all cohorts. The model is applied by Division but to simplify the description we do not indicate this in notation. Let L_{ay} denote the model values for L@A with cohort values of $L_{c\infty}$ and k_c, where $c = y-a$. We assume $E\{log(L_{oay})\} = log(L_{ay})$ and do not make a correction for the log transformation bias which should be small when the estimation error is small. The conditional variance is assumed to be the same for all ages and years; that is $Var\left[\log\left(L_{oay}\right)\middle|\{L_{o\infty c}, k_c\}\right] = \sigma_e^2$. We use the $\{\}$ notation to denote sets, so $\{L_{o\infty c}, k_c\}$ is the set of all VonB random effects for all cohorts. The log-likelihood term for the observed lengths conditional on $\{L_{o\infty c}, k_c\}$ is

(3) $$l\left(\{L_{oay}\}|\rho_o, \sigma_e^2, \{L_{o\infty c}, k_c\}\right) = \sum_a \sum_y log\left(\sigma_e^{-1}\varphi_N\left[\frac{\log(L_{oay}) - \log(L_{ay})}{\sigma_e}\right]\right),$$

where φ_N is the probability distribution function (pdf) of a *N(0,1)* random variable.

The unconditional (aka marginal) log-likelihood of the observed lengths which we use to estimate model parameters (i.e. fixed effects) requires that the $\{L_{o\infty c}, k_c\}$ random effects be integrated out of the joint likelihood for the observations and random effects. This joint likelihood is based on Eqn. (3) and log-likelihoods for $\{L_{o\infty c}, k_c\}$. Each random effect is modelled as a main effect (L_∞ or k) times a cohort-specific deviation and these deviations are modelled as lognormally distributed random walks, with zero log-means for the first cohort. Note that L_∞ or k are parameters to estimate whereas cohort-specific $L_{o\infty c}$ and k_c are random effects. The variance of each random walk are denoted σ_∞^2 or σ_k^2.

The total parameters to estimate are $\theta = (\rho_o, L_\infty, k, \sigma_e^2, \sigma_\infty^2, \sigma_k^2)$. They are estimated via maximum likelihood (MLE) based on the marginal likelihood, $L(\theta)$. Let Ψ denote a vector of all random effects for all cohorts. The marginal likelihood is

(4) $$L(\theta) = \int\int_{\Psi} f_\theta([L_{oay}]|\Psi) g_\theta(\Psi) d\Psi$$

where $f_\theta([L_{oay}]|\Psi)$ is the conditional joint pdf of the data, whose log likelihood is given by Eqn. (3), and $g_\theta(\Psi)$ is the joint pdf for the Ψ random walk effects.

The template model builder (TMB; Kristensen et al. 2015) package within R (R Core Team 2014) was used to implement the model. The MLE's of θ maximize $L(\theta)$. The user has to provide C++ computer code to calculate $f_\theta([L_{oay}]|\Psi)$ and $g_\theta(\Psi)$ but the integration in Eqn. (4) is provided by TMB. The high dimensional integral is numerically evaluated in TMB using the Laplace approximation. The random effects Ψ can be predicted by maximizing the joint likelihood, $f_\theta([L_{oay}]|\Psi) g_\theta(\Psi)$; however, these effects are not freely estimated like θ. Additional information on these procedures is provided by Skaug and Fournier (2006). TMB uses automatic differentiation to evaluate the gradient function of Eqn. (4) and in the Laplace approximation. The gradient function is produced automatically from $f_\theta([L_{oay}]|\Psi)$ and $g_\theta(\Psi)$. This greatly improves parameter estimation using a derivative-based optimizer. We use the *nlminb* function within R (R Core Team 2014) to find the MLE for θ.

RESULTS

Three models were investigated:

1. a constant L_∞ and k for all cohorts for comparison purposes;
2. a random walk in $L_{c\infty}$ and k_c across cohorts; and
3. a random walk in $L_{c\infty}$ but a constant k.

Fit statistics and parameters estimates (Table 1) indicate that model 2) was the most parsimonious. Estimates of $L_{c\infty}$ (Fig. 4) generally increased since the 1980 cohort in Divisions 2J and 3K, but not in 3L. Estimates of k declined for the same cohorts in 2K and 3K (Fig. 5), but the random cohort effect variance was estimated to be very small for 3L (Table 1) and so the estimates of k were constant across cohorts for this Division. There is a well-known confounding between estimates of L_∞ and k in the VonB model which could be contributing to some of the variations in Figs 4 and 5. However, estimates of L@A (Fig. 6) indicate a reduction through the 1980s followed by overall increases in 2J and 3K during 1995-2012 but not in 3L. The recent increases were of lower magnitude than the reductions in the 1980s. There are some surprising consistencies in the trends and short-term variations across Divisions that is worthy of further investigation.

The model predicts observed lengths fairly well (Figs 7-16) but with some evidence of lack of fit, especially in 2J and 3K during the 1980s (Figs 7-8). The model over-estimates length at ages 4-6 and under-estimates length at ages 8-10 during 1983-1989 (e.g. Fig. 7). A similar pattern exists in 3K (Fig. 8) and perhaps 3L (Fig. 9). There are correlated residuals for blocks of ages and years (Figs 14-16). However, the overall correspondence between model estimates of L@A and survey averages is good (Fig. 17), with larger discrepancies at larger sizes, presumably those with lower survey sample sizes.

Estimates of beginning-of-year L@A are shown in Fig. 18. While the overall size of cod at the start of the year is estimated to be smaller than during the DFO autumn survey (i.e. Fig. 6), changes across years follow the same patterns as expected. We use the model to estimate L@A at the midpoint of annual quarters (i.e. ages $a + 0.125$, $a + 0.375$, etc.) in NAFO Divisions 2J, 3K, and 3L (Tables 2-13). ***These predicted lengths are the ones we propose to use to infer age from the size of tagged cod for the 2015 framework assessment of Ncod***. The L@A will be based on the Division and quarter in which cod were tagged.

A total of 155 otoliths were recovered from tagged fish caught in NAFO Division 2J (1), 3K (13), and 3L (141). The recovery period spanned from 1997 until 2014 with most otoliths recovered in 2001 (Fig 19a). The release lengths of the fish whose otoliths were recovered ranged from 44 cm to 90 cm, which is smaller than the range of fish tagged (17 cm to 140 cm). The otoliths were aged at recapture and then ages were back-calculated to the time of tagging. A comparison of the model-estimated and otolith-measured ages indicates a small bias in our growth model estimates (Fig 19b); the model ages are slightly overestimated for young fish (ages 2-6). The age-length relationship using the otolith estimated ages has a much larger variance within age bins (Fig 19c,d). Variation between age bins is sometimes smaller than within age bins.

DISCUSSION

A. We implemented a VonB growth model for Northern cod length-at-age and used this model to estimate the age of a tagged fish based on its length at release, time of tagging, and location (i.e. NAFO Division). We compared these estimated ages with measured ages obtained from a small (n = 155) subsample of tagged cod that were recaptured and otoliths provided for aging. The results indicated the model estimated ages generally agree with the otolith estimated ages, although a bias exists for younger fish with model estimated ages usually greater than otolith estimated ages. Some of the otolith estimates ages seem unusual. For example, tagged cod aged two and three, and a 13 year old 70 cm cod. Errors in the reported recapture year will also affect the back-calculated age when tagged. A more definitive assessment of the VonB model's performance would require more otoliths from tagged fish and from all three NAFO Divisions.

B. Alternatively, otoliths from commercial fisheries could be used to assess the models performance. However, another issue to address is the effect of gear selectivity on the ages of fish captured. This could lead to differences in size at age for tagged and recaptured fish compared to the relatively un-selective DFO RV survey. Tagged fish were captured using primarily handlines and the DFO RV trawl, but only fish greater than 45 cm were tagged which is a knife-edged selectivity function of length. The primary gear used in the fishery are gillnets which have a domed selectivity. Addressing these issues may lead to improved age estimation for tagged cod.

C. The model we used was fairly simple and made many assumptions. This was for expediency purposes. VonB model residual analyses indicated some systematic patterns that suggest further improvements may be possible. In unreported analyses we explored model variants that included a biphasic growth model using an approximate age-at-maturity (Quince et al. 2008) and a VonB model with a quadratic k term included. These approaches did not result in improved growth models. Further investigations should use individual length-at-age measurements rather than only the average length as used in this paper. The sample sizes for different years and ages are probably highly variable and this is important information to include in a more rigorous statistical analysis of this data. Additional spatial variation in growth rates and low sample sizes at older ages may be contributing to some of the residual patterns. A more rigorous statistical analysis of temporal and spatial variability in growth rates should also account for possible environmental variations common to many cohorts, between-individual variation in growth rates, within-individual variation from the VonB model, measurement error in size and age, and the length-stratified (i.e. size biased) sampling design used to collect biological samples in the research survey. Additional growth information is also available from spring DFO RV and the Centre for Fisheries Ecosystems

Research acoustic spawning surveys, and from sampling of stewardship and Sentinel fisheries and from tagging studies, although an additional complication of the commercial sources of data, as indicated above, is the selectivity of the fishing gears which can introduce biased data when between-individual variation in growth rates is large. Such an investigation is well beyond the scope of this paper but may be necessary to provide more realistic estimation of size for a broad range of ages for Ncod.

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APPENDIX I - TABLES

Table 1. Fit statistics and parameter estimates for three formulations of the Von Bertalanffy (VonB) growth model. Minimum values of AIC and BIC, goodness of fit statistics are shaded in gray. The model indicated as $t_0 = L_\infty$ did not include random cohort effects for these parameters. "cohort indicates a model with random cohort effects in the corresponding component

Statistic	$t_0 = L_\infty$	t_0~cohort = L_∞~cohort	t_0= L_∞~cohort
Deviance	-22760.2311	-24937.1168	-24939.0038
No. parms.	10	16	13
AIC	-22740.2311	-24905.1168	-24913.0038
BIC	-21981.8115	-23977.7752	-23973.0867
MSE	0.0773	0.0708	0.0693
2J L_∞	120.9463	103.0811	109.2778
3K L_∞	123.7238	107.7727	110.1468
3L L_∞	138.1582	113.3548	152.0708
2J k	0.0864	0.1703	0.1302
3K k	0.0852	0.1438	0.1112
3L k	0.0813	0.0987	0.0895
2J p_1(%)	4.1075	2.9369	1.4634
3K p_1(%)	1.1763	0.2772	0.0000
3L p_1(%)	0.0113	0.0000	0.0000
2J σ_{ac}	-	0.0229	0.0222
3K σ_{ac}	-	0.0235	0.0119
3L σ_{ac}	-	0.0119	0.0119
2J σ_0	-	0.0305	-
3K σ_0	-	0.0243	-
3L σ_0	-	0.0000	-
σ_ε	0.0773	0.0708	0.0691

Table 2. Wardhaven unit strength strength in NATO Division 2-U quarter II.

Division	Regt 1	Regt 2	Regt 3	Regt 4	Regt 5	Regt 6	Regt 7	Regt 8	Regt 9	Regt 10	Regt 11	Regt 12
H3770	112	125	104	111	142	110	127	104	111	103	104	107
H3771	119	122	125	108	111	104	115	122	103	106	103	103
H3772	114	125	124	115	142	124	114	121	107	102	114	115
H3773	114	127	125	104	112	117	118	107	104	104	102	115
H3774	113	123	122	110	112	117	118	110	110	108	104	103
H3775	113	124	122	117	111	118	111	110	110	104	107	103
H3776	113	124	127	115	110	111	111	121	115	107	111	104
H3777	113	111	122	110	111	111	111	121	115	107	111	104
H3778	113	124	122	117	111	118	111	110	110	104	107	103
H3779	113	124	127	115	110	111	111	121	115	107	111	104
H3780	113	124	122	117	111	118	111	110	110	104	107	103
H3781	113	124	127	115	110	111	111	121	115	107	111	104
H3782	113	124	122	117	111	118	111	110	110	104	107	103
H3783	113	124	127	115	110	111	111	121	115	107	111	104
H3784	113	124	122	117	111	118	111	110	110	104	107	103
H3785	113	124	127	115	110	111	111	121	115	107	111	104
H3786	113	124	122	117	111	118	111	110	110	104	107	103
H3787	113	124	127	115	110	111	111	121	115	107	111	104
H3788	113	124	122	117	111	118	111	110	110	104	107	103
H3789	113	124	127	115	110	111	111	121	115	107	111	104
H3790	113	124	122	117	111	118	111	110	110	104	107	103
H3791	113	124	127	115	110	111	111	121	115	107	111	104
H3792	113	124	122	117	111	118	111	110	110	104	107	103
H3793	113	124	127	115	110	111	111	121	115	107	111	104
H3794	113	124	122	117	111	118	111	110	110	104	107	103
H3795	113	124	127	115	110	111	111	121	115	107	111	104
H3796	113	124	122	117	111	118	111	110	110	104	107	103
H3797	113	124	127	115	110	111	111	121	115	107	111	104
H3798	113	124	122	117	111	118	111	110	110	104	107	103
H3799	113	124	127	115	110	111	111	121	115	107	111	104
H3800	113	124	122	117	111	118	111	110	110	104	107	103
H3801	113	124	127	115	110	111	111	121	115	107	111	104
H3802	113	124	122	117	111	118	111	110	110	104	107	103
H3803	113	124	127	115	110	111	111	121	115	107	111	104
H3804	113	124	122	117	111	118	111	110	110	104	107	103
H3805	113	124	127	115	110	111	111	121	115	107	111	104
H3806	113	124	122	117	111	118	111	110	110	104	107	103
H3807	113	124	127	115	110	111	111	121	115	107	111	104
H3808	113	124	122	117	111	118	111	110	110	104	107	103
H3809	113	124	127	115	110	111	111	121	115	107	111	104
H3810	113	124	122	117	111	118	111	110	110	104	107	103
H3811	113	124	127	115	110	111	111	121	115	107	111	104
H3812	113	124	122	117	111	118	111	110	110	104	107	103

Table 3. Northern cod length-at-age in NAFO Division 2J, quarter 2.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1978	18.05	28.23	36.40	44.20	51.68	59.34	67.85	72.71	77.09	81.18	84.72	87.94
1979	17.50	27.63	36.67	43.65	50.55	57.29	64.35	72.36	76.63	80.48	84.11	87.26
1980	17.03	26.78	35.90	43.97	49.93	56.04	62.14	68.67	76.24	80.00	83.40	86.64
1981	16.81	26.08	34.83	43.06	50.27	55.35	60.79	66.33	72.41	79.59	82.92	85.92
1982	16.13	25.74	33.95	41.80	49.25	55.72	60.04	64.90	69.95	75.63	82.48	85.43
1983	16.17	24.72	33.54	40.79	47.85	54.60	60.42	64.10	68.45	73.09	78.42	84.96
1984	16.29	24.79	32.25	40.34	46.73	53.08	59.22	64.49	67.61	71.52	75.80	80.82
1985	16.49	24.97	32.37	38.87	46.28	51.90	57.62	63.22	68.00	70.64	74.18	78.14
1986	16.31	25.28	32.63	39.04	44.67	51.46	56.39	61.55	66.68	71.03	73.27	76.47
1987	15.65	25.01	33.04	39.37	44.91	49.77	55.97	60.30	64.96	69.67	73.65	75.54
1988	15.31	24.00	32.71	39.89	45.31	50.07	54.24	59.91	63.70	67.92	72.25	75.91
1989	15.59	23.46	31.43	39.52	45.93	50.55	54.61	58.16	63.35	66.65	70.48	74.49
1990	16.16	23.89	30.76	38.04	45.56	51.26	55.17	58.60	61.61	66.35	69.22	72.69
1991	15.95	24.76	31.33	37.28	43.92	50.90	55.97	59.23	62.11	64.63	68.97	71.45
1992	16.18	24.44	32.48	38.00	43.11	49.16	55.63	60.13	62.82	65.20	67.28	71.25
1993	16.00	24.78	32.08	39.40	43.97	48.33	53.82	59.82	63.79	65.98	67.92	69.61
1994	16.54	24.50	32.53	38.96	45.61	49.33	52.99	57.97	63.52	67.03	68.76	70.31
1995	16.80	25.33	32.18	39.51	45.14	51.17	54.13	57.16	61.66	66.80	69.89	71.22
1996	16.61	25.73	33.26	39.12	45.81	50.70	56.16	58.43	60.89	64.95	69.71	72.41
1997	15.75	25.43	33.80	40.43	45.38	51.48	55.71	60.64	62.28	64.22	67.87	72.28
1998	16.60	24.10	33.41	41.08	46.90	51.04	56.59	60.21	64.65	65.73	67.20	70.47
1999	16.84	25.41	31.68	40.63	47.67	52.74	56.16	61.19	64.27	68.25	68.82	69.87
2000	16.81	25.77	33.39	38.58	47.17	53.61	58.02	60.77	65.34	67.91	71.48	71.60
2001	17.15	25.72	33.87	40.64	44.04	53.08	58.98	62.79	64.95	69.08	71.20	74.37
2002	17.19	26.23	33.81	41.22	47.21	50.53	58.43	63.83	67.09	68.71	72.44	74.15
2003	17.00	26.30	34.49	41.17	47.90	53.18	55.71	63.28	68.21	70.97	72.12	75.48
2004	17.04	25.99	34.58	41.98	47.85	53.96	58.59	60.41	67.66	72.16	74.48	75.19
2005	17.20	26.05	34.18	42.10	48.79	53.91	59.46	63.50	64.69	71.63	75.74	77.65
2006	16.81	26.31	34.27	41.64	48.95	54.98	59.42	64.45	67.95	68.57	75.22	78.97
2007	17.02	25.69	34.59	41.75	48.43	55.18	60.60	64.43	68.98	71.99	72.10	78.47
2008	17.47	26.02	33.80	42.15	48.56	54.61	60.84	65.71	68.98	73.09	75.66	75.31
2009	17.49	26.71	34.23	41.19	49.02	54.77	60.24	65.98	70.35	73.11	76.82	78.98
2010	17.87	26.75	35.13	41.70	47.93	55.29	60.43	65.37	70.66	74.56	76.87	80.20
2011	18.03	27.33	35.17	42.79	48.52	54.08	61.00	65.58	70.03	74.92	78.39	80.28
2012	18.18	27.58	35.93	42.84	49.76	54.74	59.69	66.20	70.28	74.28	78.79	81.86

Table 4. Northern cod length-at-age in NAFO Division 2J, quarter 3.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1978	20.58	30.45	38.31	45.87	53.16	60.66	69.04	73.74	77.98	81.95	85.39	88.52
1979	19.94	29.81	38.60	45.31	52.00	58.57	65.49	73.38	77.52	81.25	84.78	87.83
1980	19.41	28.90	37.79	45.63	51.36	57.30	63.24	69.66	77.13	80.77	84.07	87.22
1981	19.16	28.15	36.67	44.69	51.71	56.59	61.88	67.29	73.26	80.35	83.58	86.49
1982	18.38	27.79	35.75	43.40	50.66	56.96	61.11	65.84	70.78	76.37	83.13	86.00
1983	18.43	26.70	35.33	42.35	49.23	55.82	61.50	65.03	69.26	73.80	79.05	85.53
1984	18.57	26.78	33.99	41.90	48.09	54.28	60.28	65.41	68.41	72.22	76.41	81.37
1985	18.79	26.98	34.12	40.39	47.64	53.08	58.66	64.13	68.80	71.34	74.78	78.67
1986	18.59	27.31	34.39	40.58	46.01	52.64	57.42	62.45	67.47	71.72	73.87	77.00
1987	17.83	27.02	34.83	40.93	46.26	50.94	57.01	61.20	65.74	70.35	74.25	76.05
1988	17.43	25.94	34.49	41.47	46.68	51.26	55.27	60.82	64.48	68.59	72.84	76.43
1989	17.75	25.36	33.15	41.10	47.33	51.76	55.65	59.07	64.14	67.33	71.06	75.00
1990	18.40	25.83	32.46	39.57	46.95	52.50	56.23	59.52	62.40	67.04	69.81	73.20
1991	18.16	26.77	33.07	38.80	45.29	52.14	57.06	60.17	62.92	65.32	69.57	71.96
1992	18.41	26.43	34.28	39.56	44.47	50.38	56.72	61.09	63.65	65.92	67.89	71.77
1993	18.21	26.79	33.87	41.02	45.37	49.54	54.90	60.79	64.64	66.71	68.55	70.14
1994	18.82	26.50	34.34	40.56	47.06	50.58	54.08	58.93	64.38	67.78	69.41	70.87
1995	19.12	27.39	33.98	41.15	46.59	52.47	55.25	58.13	62.52	67.56	70.55	71.78
1996	18.90	27.83	35.12	40.74	47.28	52.00	57.33	59.43	61.76	65.71	70.38	72.99
1997	17.92	27.50	35.69	42.11	46.85	52.81	56.88	61.68	63.18	65.00	68.55	72.88
1998	18.88	26.06	35.28	42.79	48.42	52.37	57.78	61.27	65.59	66.54	67.90	71.08
1999	19.15	27.48	33.47	42.33	49.21	54.11	57.36	62.27	65.22	69.09	69.55	70.49
2000	19.12	27.87	35.27	40.20	48.70	55.00	59.26	61.86	66.31	68.77	72.23	72.24
2001	19.50	27.82	35.78	42.34	46.32	54.47	60.24	63.90	65.92	69.95	71.96	75.05
2002	19.55	28.37	35.72	42.95	48.76	51.87	59.69	64.96	68.10	69.60	73.23	74.84
2003	19.33	28.44	36.43	42.90	49.47	54.58	56.93	64.42	69.23	71.88	72.92	76.19
2004	19.37	28.11	36.53	43.75	49.42	55.38	59.86	61.52	68.69	73.09	75.30	75.91
2005	19.56	28.18	36.11	43.88	50.40	55.34	60.75	64.65	65.69	72.56	76.58	78.39
2006	19.11	28.45	36.20	43.40	50.56	56.44	60.72	65.62	69.00	69.49	76.06	79.72
2007	19.35	27.79	36.55	43.51	50.03	56.64	61.92	65.61	70.04	72.94	72.94	79.23
2008	19.86	28.15	35.71	43.93	50.17	56.07	62.17	66.91	70.05	74.05	76.52	76.07
2009	19.89	28.89	36.16	42.93	50.65	56.23	61.57	67.19	71.44	74.09	77.70	79.77
2010	20.32	28.93	37.11	43.47	49.52	56.77	61.76	66.57	71.77	75.55	77.75	81.00
2011	20.50	29.56	37.15	44.59	50.13	55.53	62.34	66.80	71.13	75.92	79.29	81.08
2012	20.68	29.83	37.96	44.64	51.40	56.20	61.02	67.42	71.38	75.28	79.70	82.68

Table 5. Northern cod length-at-age in NAFO Division 2J, quarter 4.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1978	23.01	32.60	40.16	47.49	54.58	61.94	70.18	74.74	78.84	82.70	86.03	89.07
1979	22.31	31.91	40.46	46.90	53.40	59.80	66.59	74.37	78.38	81.99	85.43	88.39
1980	21.71	30.95	39.61	47.24	52.74	58.51	64.31	70.61	77.98	81.51	84.71	87.77
1981	21.43	30.15	38.44	46.27	53.10	57.78	62.92	68.21	74.08	81.09	84.22	87.05
1982	20.56	29.77	37.49	44.93	52.02	58.16	62.15	66.74	71.58	77.07	83.77	86.55
1983	20.62	28.61	37.06	43.86	50.56	56.99	62.53	65.92	70.04	74.49	79.66	86.08
1984	20.77	28.70	35.67	43.41	49.41	55.43	61.29	66.31	69.18	72.90	77.01	81.90
1985	21.02	28.92	35.81	41.87	48.95	54.23	59.66	65.01	69.57	72.00	75.37	79.19
1986	20.79	29.28	36.10	42.07	47.31	53.79	58.42	63.32	68.23	72.39	74.44	77.50
1987	19.95	28.97	36.57	42.43	47.57	52.08	58.01	62.06	66.49	71.01	74.82	76.55
1988	19.50	27.82	36.22	43.00	48.01	52.41	56.27	61.69	65.23	69.24	73.41	76.92
1989	19.85	27.21	34.83	42.63	48.68	52.93	56.67	59.94	64.90	67.98	71.62	75.49
1990	20.58	27.71	34.11	41.07	48.31	53.69	57.26	60.41	63.17	67.70	70.37	73.69
1991	20.31	28.73	34.76	40.28	46.62	53.34	58.11	61.08	63.71	66.00	70.15	72.46
1992	20.59	28.36	36.04	41.07	45.79	51.56	57.79	62.02	64.45	66.61	68.48	72.28
1993	20.36	28.76	35.61	42.59	46.73	50.72	55.95	61.73	65.46	67.42	69.16	70.66
1994	21.05	28.44	36.11	42.13	48.47	51.79	55.13	59.87	65.21	68.50	70.03	71.40
1995	21.38	29.40	35.74	42.74	47.99	53.74	56.33	59.08	63.35	68.30	71.19	72.33
1996	21.13	29.87	36.94	42.33	48.72	53.27	58.46	60.40	62.60	66.45	71.04	73.55
1997	20.03	29.52	37.53	43.75	48.29	54.10	58.02	62.70	64.05	65.76	69.21	73.46
1998	21.11	27.98	37.11	44.46	49.90	53.66	58.95	62.29	66.50	67.32	68.58	71.67
1999	21.41	29.50	35.21	43.98	50.71	55.45	58.52	63.32	66.14	69.91	70.25	71.10
2000	21.37	29.92	37.10	41.78	50.20	56.36	60.46	62.91	67.26	69.60	72.97	72.87
2001	21.80	29.87	37.64	44.01	47.76	55.82	61.46	64.99	66.88	70.80	72.71	75.71
2002	21.85	30.46	37.58	44.64	50.27	53.18	60.92	66.07	69.08	70.46	74.00	75.51
2003	21.60	30.54	38.32	44.59	51.00	55.95	58.12	65.52	70.24	72.77	73.69	76.88
2004	21.65	30.18	38.43	45.47	50.95	56.77	61.10	62.60	69.70	74.00	76.10	76.62
2005	21.86	30.26	38.00	45.61	51.96	56.73	62.01	65.78	66.68	73.47	77.39	79.11
2006	21.35	30.55	38.09	45.11	52.14	57.86	61.99	66.77	70.02	70.38	76.89	80.46
2007	21.63	29.84	38.46	45.23	51.59	58.07	63.22	66.76	71.08	73.87	73.75	79.98
2008	22.20	30.22	37.58	45.67	51.74	57.49	63.47	68.08	71.10	75.00	77.36	76.81
2009	22.23	31.02	38.05	44.64	52.23	57.67	62.86	68.38	72.50	75.03	78.55	80.53
2010	22.71	31.06	39.05	45.19	51.08	58.21	63.06	67.75	72.04	76.52	78.61	81.78
2011	22.92	31.73	39.09	46.36	51.70	56.95	63.66	67.98	72.21	76.90	80.17	81.86
2012	23.11	32.02	39.93	46.41	53.01	57.63	62.31	68.62	72.47	76.26	80.59	83.48

Table 6. *Northern cod length-at-age in NAFO Division 3K, quarter 1.*

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1978	14.25	25.07	34.32	42.87	51.82	60.54	68.40	74.69	78.78	81.70	83.91	87.46
1979	14.04	25.01	34.50	42.53	50.10	58.33	66.40	73.63	79.30	82.78	85.15	86.88
1980	13.65	24.63	34.40	42.74	49.70	56.42	64.02	71.51	78.18	83.30	86.26	88.16
1981	13.39	23.97	33.87	42.60	49.93	55.98	61.95	68.98	75.97	82.14	86.79	89.28
1982	12.87	23.53	32.99	41.93	49.75	56.23	61.47	66.79	73.31	79.85	85.59	89.83
1983	12.73	22.65	32.42	40.87	48.97	56.00	61.72	66.27	71.01	77.10	83.23	88.59
1984	12.82	22.44	31.27	40.22	47.77	55.11	61.46	66.53	70.47	74.71	80.40	86.18
1985	12.93	22.61	31.02	38.86	47.05	53.79	60.47	66.22	70.72	74.14	77.94	83.29
1986	12.65	22.82	31.27	38.59	45.54	53.05	59.06	65.15	70.37	74.39	77.35	80.76
1987	12.13	22.36	31.59	38.93	45.27	51.43	58.30	63.67	69.23	74.00	77.60	80.15
1988	12.20	21.49	31.00	39.35	45.71	51.18	56.61	62.90	67.70	72.79	77.17	80.40
1989	12.50	21.63	29.85	38.68	46.24	51.70	56.39	61.17	66.94	71.22	75.90	79.94
1990	13.01	22.17	30.09	37.33	45.52	52.34	57.00	60.99	65.18	70.48	74.30	78.61
1991	12.92	23.09	30.85	37.66	44.02	51.60	57.75	61.69	65.06	68.72	73.58	76.99
1992	12.65	22.95	32.14	38.65	44.45	50.00	57.01	62.54	65.84	68.65	71.83	76.30
1993	12.82	22.48	31.98	40.27	45.65	50.54	55.35	61.82	66.78	69.50	71.81	74.57
1994	12.60	22.80	31.36	40.11	47.57	51.93	56.00	60.13	66.10	70.55	72.75	74.61
1995	12.53	22.43	31.81	39.38	47.43	54.13	57.57	60.89	64.40	69.91	73.88	75.62
1996	12.66	22.30	31.32	39.95	46.62	54.03	60.02	62.63	65.27	68.22	73.30	76.84
1997	12.96	22.54	31.15	39.37	47.31	53.15	59.96	65.32	67.17	69.20	71.64	76.31
1998	12.58	23.08	31.49	39.17	46.65	53.95	59.05	65.31	70.07	71.25	72.72	74.70
1999	12.73	22.42	32.26	39.62	46.44	53.25	59.95	64.38	70.12	74.34	74.91	75.88
2000	12.98	22.70	31.37	40.60	46.99	53.02	59.21	65.38	69.19	74.46	78.18	78.20
2001	12.70	23.13	31.77	39.51	48.16	53.67	58.99	64.62	70.27	73.53	78.36	81.63
2002	13.03	22.65	32.36	40.01	46.92	55.02	59.73	64.39	69.50	74.70	77.44	81.88
2003	13.11	23.22	31.71	40.76	47.52	53.65	61.24	65.23	69.29	73.93	78.70	80.98
2004	12.98	23.37	32.49	39.95	48.39	54.35	59.78	66.89	70.21	73.73	77.93	82.31
2005	12.68	23.14	32.69	40.92	47.46	55.34	60.56	65.35	72.01	74.74	77.75	81.56
2006	12.58	22.62	32.39	41.18	48.59	54.29	61.66	66.21	70.41	76.66	78.83	81.39
2007	12.78	22.45	31.67	40.81	48.90	55.56	60.51	67.40	71.35	75.02	80.88	82.55
2008	13.12	22.80	31.44	39.93	48.47	55.91	61.90	66.17	72.62	76.02	79.21	84.70
2009	13.15	23.40	31.93	39.65	47.45	55.44	62.30	67.67	71.32	77.38	80.28	83.02
2010	13.58	23.44	32.75	40.25	47.13	54.31	61.79	68.10	72.91	76.01	81.70	84.15
2011	13.57	24.19	32.81	41.25	47.83	53.95	60.56	67.56	73.38	77.68	80.28	85.63
2012	13.78	24.18	33.84	41.33	49.00	54.74	60.18	66.26	72.82	78.18	82.02	84.17

Table 7. Northern cod length-at-age in NAFO Division 3K, quarter 2.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1978	17.08	27.55	36.48	44.77	53.53	62.08	69.77	75.90	79.83	82.61	84.69	88.14
1979	16.82	27.48	36.66	44.41	51.76	59.82	67.75	74.82	80.35	83.69	85.94	87.57
1980	16.36	27.06	36.56	44.63	51.35	57.88	65.32	72.69	79.22	84.22	87.05	88.85
1981	16.05	26.34	35.99	44.48	51.59	57.42	63.22	70.12	76.99	83.05	87.59	89.98
1982	15.43	25.87	35.06	43.78	51.40	57.67	62.73	67.90	74.31	80.74	86.38	90.52
1983	15.27	24.91	34.47	42.68	50.59	57.44	62.99	67.37	71.98	77.97	84.01	89.28
1984	15.38	24.69	33.26	42.01	49.35	56.52	62.71	67.63	71.43	75.56	81.16	86.86
1985	15.51	24.87	33.00	40.61	48.63	55.18	61.70	67.31	71.69	74.98	78.68	83.95
1986	15.18	25.11	33.27	40.34	47.08	54.42	60.27	66.22	71.33	75.23	78.08	81.41
1987	14.57	24.61	33.62	40.70	46.82	52.78	59.51	64.73	70.17	74.84	78.33	80.80
1988	14.66	23.67	33.00	41.15	47.27	52.54	57.80	63.96	68.62	73.61	77.90	81.04
1989	15.01	23.83	31.80	40.47	47.83	53.09	57.60	62.22	67.87	72.03	76.61	80.57
1990	15.63	24.43	32.06	39.08	47.10	53.75	58.23	62.06	66.11	71.29	75.01	79.24
1991	15.53	25.44	32.88	39.43	45.58	53.01	59.00	62.77	66.00	69.53	74.29	77.61
1992	15.20	25.30	34.25	40.47	46.04	51.40	58.27	63.65	66.80	69.48	72.55	76.92
1993	15.41	24.79	34.09	42.17	47.28	51.96	56.59	62.94	67.77	70.35	72.55	75.21
1994	15.15	25.14	33.45	42.01	49.28	53.39	57.27	61.24	67.10	71.42	73.50	75.26
1995	15.06	24.74	33.92	41.26	49.15	55.66	58.88	62.03	65.40	70.80	74.65	76.28
1996	15.22	24.59	33.41	41.86	48.32	55.57	61.40	63.81	66.29	69.12	74.09	77.52
1997	15.58	24.86	33.23	41.26	49.03	54.68	61.35	66.56	68.23	70.12	72.44	77.01
1998	15.13	25.46	33.60	41.05	48.36	55.51	60.43	66.56	71.18	72.20	73.54	75.41
1999	15.31	24.74	34.42	41.53	48.14	54.80	61.36	65.63	71.25	75.34	75.77	76.61
2000	15.60	25.05	33.48	42.56	48.72	54.57	60.62	66.65	70.31	75.47	79.08	78.97
2001	15.28	25.52	33.90	41.43	49.93	55.24	60.39	65.88	71.42	74.54	79.28	82.43
2002	15.67	25.00	34.54	41.96	48.66	56.63	61.16	65.66	70.65	75.74	78.36	82.70
2003	15.76	25.62	33.84	42.74	49.29	55.24	62.70	66.52	70.44	74.97	79.64	81.81
2004	15.61	25.78	34.67	41.89	50.19	55.95	61.22	68.21	71.39	74.77	78.87	83.16
2005	15.25	25.54	34.89	42.91	49.22	56.98	62.02	66.66	73.21	75.80	78.69	82.41
2006	15.13	24.96	34.57	43.18	50.39	55.90	63.14	67.54	71.61	77.75	79.80	82.25
2007	15.38	24.78	33.81	42.79	50.71	57.20	61.97	68.75	72.56	76.11	81.87	83.43
2008	15.78	25.16	33.57	41.88	50.28	57.57	63.39	67.50	73.85	77.13	80.20	85.60
2009	15.81	25.82	34.08	41.58	49.23	57.09	63.80	69.02	72.53	78.49	81.28	83.92
2010	16.33	25.87	34.95	42.21	48.90	55.93	63.28	69.47	74.14	77.12	82.71	85.06
2011	16.32	26.69	35.01	43.26	49.62	55.56	62.03	68.92	74.63	78.80	81.29	86.55
2012	16.57	26.68	36.11	43.34	50.82	56.37	61.65	67.60	74.06	79.31	83.04	85.08

Table 6. Northern cod length-at-age in NAFO Division 3K, quarter 3.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1978	19.81	29.94	38.56	46.61	55.18	63.57	71.10	77.07	80.85	83.49	85.45	88.81
1979	19.51	29.86	38.76	46.24	53.37	61.27	69.05	75.98	81.37	84.58	86.71	88.23
1980	18.98	29.41	38.64	46.46	52.95	59.28	66.58	73.82	80.23	85.11	87.82	89.51
1981	18.63	28.63	38.04	46.30	53.19	58.82	64.45	71.22	77.98	83.93	88.38	90.65
1982	17.92	28.12	37.06	45.57	52.98	59.07	63.95	68.97	75.27	81.60	87.14	91.19
1983	17.74	27.10	36.45	44.43	52.15	58.82	64.21	68.44	72.92	78.81	84.76	89.94
1984	17.86	26.86	35.19	43.75	50.88	57.88	63.92	68.70	72.36	76.38	81.90	87.51
1985	18.02	27.07	34.92	42.31	50.15	56.52	62.69	68.37	72.62	75.80	79.40	84.59
1986	17.64	27.33	35.22	42.04	48.58	55.76	61.44	67.26	72.25	76.05	78.80	82.04
1987	16.94	26.80	35.59	42.42	48.32	54.10	60.68	65.75	71.07	75.64	79.05	81.42
1988	17.05	25.79	34.95	42.90	48.79	53.86	58.96	64.99	69.52	74.40	78.60	81.66
1989	17.46	25.97	33.70	42.20	49.38	54.43	58.76	63.24	68.77	72.81	77.30	81.18
1990	18.18	26.63	33.98	40.77	48.65	55.12	59.42	63.09	67.01	72.08	75.69	79.84
1991	18.07	27.73	34.86	41.15	47.10	54.38	60.21	63.83	66.91	70.32	74.98	78.21
1992	17.69	27.58	36.31	42.24	47.58	52.75	59.49	64.73	67.73	70.28	73.25	77.53
1993	17.94	27.04	36.15	44.02	48.87	53.34	57.81	64.02	68.72	71.18	73.28	75.82
1994	17.64	27.42	35.47	43.87	50.94	54.82	58.51	62.33	68.06	72.27	74.23	75.89
1995	17.53	26.99	35.98	43.09	50.81	57.16	60.17	63.14	66.37	71.66	75.40	76.93
1996	17.72	26.83	35.45	43.72	49.97	57.07	62.74	64.96	67.29	69.98	74.85	78.19
1997	18.14	27.12	35.29	43.10	50.71	56.18	62.71	67.76	69.27	71.61	73.21	77.69
1998	17.62	27.78	35.66	42.89	50.03	57.03	61.78	67.78	72.27	73.13	74.34	76.10
1999	17.83	27.00	36.53	43.40	49.81	56.31	62.73	66.84	72.35	76.31	76.60	77.33
2000	18.17	27.34	35.54	44.47	50.41	56.08	61.98	67.89	71.41	76.46	79.95	79.72
2001	17.80	27.85	35.99	43.30	51.67	56.78	61.76	67.12	72.54	75.54	80.17	83.22
2002	18.24	27.29	36.66	43.85	50.36	58.20	62.55	66.90	71.77	76.75	79.26	83.50
2003	18.36	27.97	35.93	44.67	51.01	56.79	64.13	67.78	71.56	75.98	80.55	82.62
2004	18.18	28.14	36.80	43.79	51.95	57.52	62.63	69.51	72.53	75.79	79.79	83.98
2005	17.76	27.88	37.04	44.84	50.95	58.57	63.45	67.94	74.39	76.84	79.62	83.24
2006	17.63	27.25	36.70	45.13	52.16	57.47	64.60	68.84	72.77	78.82	80.74	83.08
2007	17.91	27.05	35.90	44.73	52.49	58.80	63.40	70.07	73.74	77.17	82.84	84.29
2008	18.38	27.47	35.64	43.79	52.04	59.18	64.85	68.80	75.06	78.20	81.16	86.48
2009	18.42	28.18	36.19	43.48	50.96	58.69	65.27	70.35	73.72	79.59	82.26	84.80
2010	19.01	28.23	37.10	44.13	50.62	57.51	64.74	70.60	75.35	78.20	83.71	85.95
2011	19.00	29.13	37.17	45.22	51.36	57.14	63.48	70.25	75.84	79.90	82.27	87.46
2012	19.30	29.12	38.32	45.30	52.60	57.96	63.08	68.91	75.26	80.42	84.03	85.98

Table 8. Wavefront wind strength storage in MMFD Elevation 99, quarter 6.

Tractor	Argon 1	Argon 2	Argon 3	Argon 4	Argon 5	Argon 6	Argon 7	Argon 8	Argon 9	Argon 10	Argon 11	Argon 12
118778	22 #6	32 28	#3 10	#9 38	39 78	91 91	72 39	78 20	91 93	5e 10	85 18	85 #3
118779	22 11	32 17	#3 79	#9 33	5e 32	82 87	79 33	77 13	82 32	92 #3	87 #3	85 87
118863	21 32	31 87	#3 #3	#9 23	5e #3	91 5e	87 83	7e 91	91 20	92 36	36 37	83 18
118871	21 12	30 5e	#3 32	#9 35	5e 79	83 17	91 5e	72 29	78 93	5e 77	85 11	91 33
118872	20 32	30 31	39 33	#7 38	5e 32	85 #2	85 13	79 31	78 20	82 #3	87 33	91 5e
118873	20 13	29 23	38 37	#8 13	93 91	83 18	91 35	85 #7	75 85	79 82	92 #3	83 35
118880	20 27	29 37	37 31	#3 #3	32 36	39 20	91 35	46 75	75 27	77 17	82 83	88 13
118882	20 #8	29 20	36 78	#3 35	91 82	37 91	5e 5e	85 35	75 32	78 38	83 36	82 21
118888	20 33	29 #3	37 13	#3 38	93 32	37 35	82 38	38 28	75 1e	78 5e	79 #3	82 82
118897	19 25	28 33	37 33	9e 38	#3 77	38 37	91 91	88 7e	71 35	78 #2	78 75	82 32
118899	19 37	27 82	36 5e	9e 38	93 27	93 13	83 38	83 39	73 38	79 16	79 28	82 27
118910	19 #8	28 36	35 5e	#3 38	93 38	93 7e	38 38	5e 23	85 5e	75 37	77 37	91 78
118983	20 37	28 77	35 5e	#2 #2	38 1e	39 #5	83 37	5e 36	87 38	72 5e	79 38	83 #2
118911	20 5e	29 36	36 78	#2 82	#8 37	38 78	91 35	5e 83	87 75	71 35	79 83	78 78
118912	20 12	29 91	38 32	#3 37	#3 38	5e 37	83 87	85 77	38 83	79 38	79 82	78 12
118913	20 #3	29 23	38 38	#2 82	38 #2	5e 83	38 38	83 38	38 83	71 38	75 38	78 91
118948	20 36	29 5e	37 #3	#2 37	32 38	38 21	38 78	83 38	38 38	75 38	7e 38	78 #3
118965	19 5e	29 38	37 38	9e 38	32 9e	38 91	91 91	5e 22	87 91	72 #3	78 13	77 38
118966	20 13	29 32	37 #3	#3 5e	91 38	38 5e	5e 38	88 38	38 28	79 82	79 38	78 83
118977	20 5e	29 38	37 21	9e 38	32 38	37 83	5e 32	83 83	79 27	71 38	75 38	78 38
118978	20 38	30 38	37 38	9e 38	91 38	38 91	83 13	83 87	75 32	7e 38	79 12	78 77
118983	20 30	29 21	38 38	#3 21	91 9e	37 78	5e 37	83 38	75 #2	77 28	77 91	78 38
200000	20 38	29 38	37 38	#8 38	32 38	37 38	83 32	38 13	72 #3	77 #3	83 38	83 5e
200001	20 25	30 13	38 82	#3 13	83 38	38 27	83 38	83 83	75 5e	79 38	91 1e	83 38
200002	20 78	29 32	38 73	#3 78	32 83	38 78	83 91	83 11	72 38	77 7e	83 13	5e 28
200003	20 38	30 28	37 38	#8 38	32 78	38 38	83 83	83 91	72 38	79 37	91 5e	83 91
200004	20 38	30 5e	38 38	#3 38	83 38	38 38	5e 38	79 78	75 38	79 78	83 83	5e 78
200005	20 22	30 13	39 13	#8 7e	32 5e	83 13	5e 5e	83 13	72 5e	77 38	83 32	5e 32
200006	20 37	29 38	38 78	#7 38	83 38	38 91	38 91	79 11	75 91	79 38	91 38	83 38
200007	20 38	29 27	37 5e	#8 82	5e 22	83 37	5e 38	71 38	7e 38	79 28	83 78	83 11
200008	20 32	29 73	37 87	#3 5e	83 78	83 78	38 27	79 38	78 28	79 28	82 13	87 5e
200009	20 38	30 38	38 2e	#3 38	32 38	83 28	38 78	71 5e	7e 38	83 38	83 22	38 38
200010	21 83	30 38	39 28	#8 38	32 91	38 38	38 17	72 11	78 38	79 28	5e 38	38 82
200011	21 82	31 91	39 28	#7 13	38 87	38 38	5e 38	71 38	77 38	83 87	83 28	38 5e
200012	21 38	31 38	40 #8	#7 22	5e 38	38 91	5e #3	79 28	78 #2	91 38	82 91	38 82

Table 10. Northern cod length-at-age in NAFO Division 3L, quarter 1.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1978	12.55	22.72	32.07	41.05	50.05	59.00	67.34	76.28	83.77	89.54	94.83	99.69
1979	12.45	22.72	32.05	40.63	48.98	57.48	65.99	73.89	82.47	89.54	94.83	99.69
1980	12.24	22.54	32.05	40.60	48.48	56.25	64.30	72.41	79.89	88.16	94.83	99.69
1981	12.13	22.16	31.80	40.61	48.45	55.68	62.92	70.55	78.29	85.39	93.37	99.69
1982	12.01	21.97	31.25	40.28	48.45	55.64	62.28	69.03	76.28	83.69	90.44	98.15
1983	12.02	21.75	30.99	39.60	48.07	55.65	62.24	68.33	74.64	81.54	88.63	95.07
1984	12.11	21.76	30.68	39.26	47.25	55.20	62.25	68.29	73.89	79.79	86.36	93.17
1985	12.05	21.93	30.69	38.87	46.85	54.26	61.75	68.30	73.84	78.98	84.50	90.78
1986	12.06	21.82	30.93	38.88	46.38	53.80	60.70	67.75	73.85	78.93	83.65	88.83
1987	12.08	21.84	30.78	39.19	46.39	53.27	60.18	66.60	73.26	78.94	83.59	87.93
1988	12.16	21.87	30.81	39.00	46.76	53.28	59.59	66.03	72.01	78.30	83.60	87.87
1989	12.27	22.02	30.85	39.03	46.53	53.70	59.60	65.38	71.40	76.97	82.93	87.88
1990	12.59	22.23	31.07	39.08	46.57	53.44	60.07	65.39	70.69	76.32	81.52	87.18
1991	12.63	22.79	31.35	39.36	46.64	53.48	59.78	65.91	70.71	75.56	80.83	85.70
1992	12.55	22.87	32.15	39.72	46.96	53.56	59.83	65.59	71.26	75.58	80.03	84.97
1993	12.46	22.72	32.26	40.73	47.39	53.94	59.91	65.64	70.92	76.17	80.05	84.12
1994	12.37	22.56	32.05	40.87	48.59	54.43	60.33	65.74	70.97	75.80	80.67	84.14
1995	12.30	22.40	31.83	40.60	48.77	55.81	60.88	66.20	71.08	75.86	80.29	84.80
1996	12.49	22.27	31.60	40.32	48.45	56.01	62.43	66.80	71.57	75.98	80.35	84.40
1997	12.65	22.61	31.41	40.03	48.11	55.64	62.65	68.50	72.23	76.51	80.47	84.46
1998	12.69	22.90	31.90	39.80	47.76	55.26	62.24	68.74	74.06	77.21	81.03	84.59
1999	12.53	22.97	32.30	40.41	47.49	54.86	61.81	68.29	74.32	79.16	81.77	85.18
2000	12.60	22.69	32.41	40.93	48.22	54.54	61.36	67.82	73.84	79.45	83.84	85.96
2001	12.46	22.81	32.00	41.06	48.83	55.38	61.01	67.33	73.33	78.93	84.14	88.14
2002	12.43	22.56	32.17	40.54	48.99	56.08	61.95	66.94	72.80	78.38	83.59	88.45
2003	12.44	22.51	31.82	40.76	48.38	56.26	62.73	67.97	72.37	77.81	83.01	87.87
2004	12.44	22.52	31.75	40.31	48.64	55.56	62.93	68.83	73.49	77.36	82.41	87.26
2005	12.29	22.53	31.77	40.22	48.10	55.86	62.15	69.05	74.43	78.56	81.93	86.63
2006	12.20	22.26	31.77	40.25	47.99	55.25	62.48	68.19	74.66	79.55	83.20	86.13
2007	12.35	22.09	31.39	40.26	48.03	55.12	61.80	68.55	73.73	79.81	84.26	87.46
2008	12.49	22.36	31.16	39.77	48.03	55.16	61.65	67.80	74.12	78.81	84.52	88.57
2009	12.63	22.61	31.54	39.47	47.46	55.17	61.70	67.65	73.31	79.23	83.47	88.85
2010	12.71	22.87	31.90	39.96	47.10	54.51	61.71	67.70	73.14	78.36	83.92	87.74
2011	12.58	23.01	32.26	40.42	47.68	54.09	60.97	67.71	73.20	78.18	83.00	88.21
2012	12.53	22.78	32.46	40.87	48.22	54.77	60.51	66.89	73.21	78.24	82.80	87.25

Table 11. Northern cod length-at-age in NAFO Division 3L, quarter 2.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1978	15.18	25.13	34.28	43.09	51.97	60.80	69.03	77.88	85.26	90.91	96.09	100.84
1979	15.05	25.13	34.26	42.66	50.85	59.24	67.65	75.44	83.94	90.91	96.09	100.84
1980	14.80	24.93	34.26	42.63	50.34	57.97	65.91	73.93	81.31	89.50	96.09	100.84
1981	14.67	24.51	33.99	42.63	50.31	57.38	64.50	72.03	79.68	86.70	94.60	100.84
1982	14.53	24.30	33.41	42.29	50.31	57.35	63.84	70.48	77.64	84.96	91.64	99.28
1983	14.53	24.06	33.13	41.57	49.91	57.35	63.80	69.77	75.97	82.78	89.80	96.17
1984	14.64	24.06	32.80	41.22	49.06	56.89	63.81	69.72	75.20	81.00	87.50	94.24
1985	14.57	24.25	32.80	40.81	48.64	55.93	63.30	69.73	75.15	80.18	85.62	91.83
1986	14.59	24.13	33.06	40.82	48.16	55.45	62.22	69.17	75.16	80.13	84.75	89.85
1987	14.61	24.15	32.90	41.14	48.17	54.90	61.69	68.00	74.56	80.14	84.70	88.94
1988	14.71	24.19	32.93	40.94	48.55	54.91	61.08	67.42	73.29	79.50	84.71	88.89
1989	14.84	24.36	32.98	40.97	48.32	55.34	61.10	66.75	72.67	78.15	84.03	88.90
1990	15.22	24.58	33.21	41.03	48.35	55.08	61.57	66.77	71.95	77.48	82.60	88.18
1991	15.27	25.20	33.51	41.32	48.42	55.12	61.28	67.29	71.96	76.71	81.90	86.68
1992	15.17	25.29	34.36	41.70	48.76	55.20	61.33	66.96	72.53	76.73	81.09	85.95
1993	15.07	25.13	34.48	42.76	49.21	55.59	61.42	67.02	72.18	77.33	81.11	85.09
1994	14.96	24.95	34.26	42.91	50.46	56.10	61.84	67.12	72.24	76.96	81.74	85.11
1995	14.87	24.77	34.02	42.63	50.64	57.52	62.41	67.58	72.34	77.02	81.35	85.78
1996	15.10	24.63	33.77	42.33	50.31	57.72	63.99	68.20	72.85	77.13	81.41	85.37
1997	15.29	25.01	33.58	42.03	49.96	57.35	64.22	69.93	73.51	77.67	81.53	85.44
1998	15.34	25.33	34.10	41.78	49.60	56.95	63.80	70.18	75.38	78.39	82.10	85.56
1999	15.15	25.41	34.53	42.43	49.31	56.54	63.36	69.72	75.65	80.37	82.85	86.16
2000	15.23	25.09	34.64	42.97	50.07	56.21	62.90	69.24	75.15	80.66	84.95	86.95
2001	15.07	25.23	34.21	43.10	50.71	57.08	62.54	68.74	74.63	80.13	85.25	89.15
2002	15.03	24.95	34.39	42.56	50.87	57.80	63.50	68.34	74.09	79.58	84.70	89.47
2003	15.04	24.89	34.01	42.79	50.23	57.98	64.31	69.40	73.66	79.00	84.11	88.88
2004	15.04	24.91	33.93	42.32	50.50	57.26	64.51	70.28	74.80	78.54	83.50	88.27
2005	14.86	24.91	33.96	42.23	49.95	57.57	63.71	70.50	75.75	79.76	83.02	87.63
2006	14.75	24.61	33.96	42.26	49.83	56.94	64.05	69.62	75.99	80.77	84.30	87.12
2007	14.93	24.43	33.56	42.26	49.87	56.80	63.35	69.99	75.04	81.02	85.37	88.47
2008	15.10	24.73	33.30	41.76	49.88	56.85	63.20	69.23	75.44	80.01	85.64	89.59
2009	15.27	25.01	33.72	41.44	49.28	56.86	63.25	69.06	74.62	80.44	84.57	89.88
2010	15.37	25.29	34.10	41.96	48.90	56.17	63.26	69.12	74.44	79.56	85.02	88.75
2011	15.21	25.45	34.48	42.43	49.51	55.75	62.50	69.13	74.50	79.37	84.09	89.23
2012	15.15	25.19	34.69	42.91	50.07	56.44	62.03	68.30	74.51	79.44	83.90	88.25

Table 12. Northern cod length-at-age in NAFO Division 3L, quarter 3.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1978	17.75	27.49	36.44	45.10	53.85	62.57	70.68	79.44	86.72	92.24	97.31	101.96
1979	17.60	27.49	36.42	44.64	52.69	60.96	69.27	76.95	85.38	92.24	97.31	101.96
1980	17.30	27.27	36.42	44.61	52.16	59.66	67.49	75.41	82.70	90.82	97.31	101.96
1981	17.16	26.80	36.13	44.62	52.12	59.05	66.04	73.48	81.05	87.97	95.81	101.96
1982	16.99	26.58	35.52	44.26	52.13	59.01	65.37	71.90	78.97	86.21	92.81	100.39
1983	16.99	26.31	35.22	43.51	51.71	59.02	65.33	71.17	77.27	84.00	90.95	97.24
1984	17.12	26.32	34.87	43.14	50.83	58.55	65.34	71.13	76.49	82.20	88.62	95.29
1985	17.04	26.53	34.87	42.71	50.40	57.55	64.82	71.13	76.44	81.36	86.71	92.85
1986	17.06	26.40	35.15	42.72	49.90	57.06	63.71	70.56	76.45	81.31	85.83	90.86
1987	17.08	26.42	34.98	43.05	49.91	56.50	63.17	69.36	75.84	81.32	85.78	89.93
1988	17.20	26.46	35.01	42.85	50.30	56.51	62.54	68.77	74.54	80.67	85.79	89.88
1989	17.36	26.64	35.06	42.88	50.06	56.95	62.56	68.09	73.91	79.30	85.10	89.89
1990	17.80	26.89	35.30	42.94	50.10	56.68	63.05	68.11	73.18	78.62	83.65	89.17
1991	17.86	27.57	35.62	43.24	50.17	56.72	62.75	68.64	73.20	77.84	82.94	87.65
1992	17.74	27.67	36.53	43.64	50.52	56.81	62.80	68.31	73.77	77.86	82.12	86.91
1993	17.62	27.49	36.66	44.75	50.99	57.20	62.89	68.37	73.41	78.47	82.14	86.04
1994	17.49	27.29	36.42	44.90	52.28	57.73	63.33	68.46	73.47	78.09	82.78	86.06
1995	17.39	27.10	36.17	44.61	52.47	59.19	63.91	68.94	73.58	78.16	82.39	86.74
1996	17.66	26.94	35.90	44.30	52.12	59.40	65.53	69.57	74.09	78.27	82.45	86.32
1997	17.88	27.36	35.70	43.98	51.76	59.01	65.76	71.34	74.77	78.82	82.57	86.39
1998	17.94	27.70	36.25	43.73	51.39	58.60	65.33	71.59	76.67	79.54	83.15	86.52
1999	17.72	27.79	36.71	44.40	51.09	58.18	64.88	71.12	76.94	81.56	83.91	87.12
2000	17.81	27.44	36.82	44.97	51.88	57.84	64.41	70.63	76.44	81.84	86.04	87.92
2001	17.62	27.59	36.36	45.11	52.54	58.74	64.03	70.12	75.91	81.31	86.34	90.15
2002	17.58	27.29	36.56	44.54	52.70	59.48	65.03	69.71	75.36	80.75	85.78	90.47
2003	17.59	27.23	36.16	44.78	52.04	59.67	65.85	70.79	74.92	80.16	85.18	89.88
2004	17.59	27.25	36.07	44.29	52.32	58.92	66.06	71.69	76.08	79.70	84.57	89.25
2005	17.38	27.25	36.10	44.19	51.75	59.24	65.23	71.92	77.05	80.93	84.08	88.61
2006	17.25	26.92	36.11	44.23	51.63	58.59	65.58	71.02	77.29	81.96	85.38	88.09
2007	17.46	26.72	35.67	44.23	51.67	58.46	64.86	71.40	76.32	82.22	86.46	89.46
2008	17.66	27.05	35.40	43.70	51.68	58.50	64.71	70.62	76.73	81.19	86.73	90.59
2009	17.86	27.36	35.84	43.37	51.06	58.51	64.77	70.45	75.89	81.62	85.65	90.88
2010	17.97	27.67	36.25	43.91	50.67	57.81	64.77	70.51	75.72	80.73	86.11	89.74
2011	17.79	27.84	36.66	44.40	51.30	57.37	64.00	70.52	75.78	80.54	85.17	90.22
2012	17.71	27.55	36.88	44.91	51.88	58.08	63.51	69.67	75.78	80.61	84.97	89.24

Table 13. Northern cod length-at-age in NAFO Division 3L, quarter 4.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1978	20.26	29.79	38.56	47.06	55.69	64.30	72.30	80.97	88.14	93.55	98.51	103.06
1979	20.10	29.80	38.53	46.58	54.49	62.65	70.86	78.44	86.78	93.55	98.51	103.06
1980	19.76	29.56	38.54	46.55	53.94	61.30	69.04	76.87	84.06	92.11	98.51	103.06
1981	19.59	29.05	38.23	46.56	53.90	60.68	67.55	74.89	82.38	89.22	96.99	103.06
1982	19.39	28.81	37.58	46.18	53.91	60.65	66.87	73.29	80.27	87.44	93.95	101.47
1983	19.40	28.52	37.26	45.40	53.48	60.65	66.83	72.54	78.54	85.19	92.07	98.29
1984	19.55	28.53	36.89	45.01	52.57	60.17	66.84	72.50	77.75	83.36	89.71	96.32
1985	19.46	28.75	36.90	44.56	52.12	59.14	66.30	72.51	77.70	82.52	87.78	93.85
1986	19.47	28.61	37.19	44.58	51.60	58.64	65.17	71.92	77.71	82.47	86.89	91.84
1987	19.50	28.64	37.01	44.92	51.62	58.06	64.62	70.70	77.08	82.47	86.84	90.90
1988	19.64	28.68	37.04	44.71	52.02	58.07	63.98	70.10	75.77	81.81	86.85	90.85
1989	19.82	28.88	37.09	44.74	51.77	58.53	63.99	69.40	75.13	80.42	86.15	90.86
1990	20.32	29.14	37.35	44.81	51.81	58.25	64.49	69.42	74.38	79.74	84.69	90.13
1991	20.39	29.88	37.69	45.12	51.89	58.29	64.18	69.96	74.40	78.95	83.97	88.60
1992	20.26	29.99	38.65	45.54	52.25	58.38	64.23	69.63	74.98	78.97	83.13	87.85
1993	20.12	29.79	38.79	46.69	52.73	58.78	64.33	69.68	74.62	79.58	83.15	86.97
1994	19.97	29.58	38.53	46.86	54.06	59.32	64.78	69.79	74.68	79.20	83.80	86.99
1995	19.86	29.37	38.27	46.55	54.26	60.83	65.37	70.27	74.79	79.26	83.40	87.67
1996	20.16	29.20	37.99	46.23	53.90	61.04	67.03	70.92	75.31	79.38	83.47	87.25
1997	20.42	29.65	37.77	45.89	53.53	60.64	67.27	72.71	76.00	79.93	83.59	87.32
1998	20.48	30.03	38.35	45.63	53.14	60.22	66.83	72.97	77.93	80.67	84.17	87.45
1999	20.23	30.12	38.84	46.33	52.83	59.79	66.36	72.50	78.21	82.71	84.94	88.06
2000	20.34	29.75	38.96	46.92	53.65	59.44	65.88	71.99	77.70	83.01	87.10	88.87
2001	20.11	29.91	38.48	47.07	54.33	60.36	65.50	71.47	77.16	82.46	87.41	91.12
2002	20.07	29.58	38.68	46.48	54.50	61.13	66.51	71.06	76.60	81.89	86.84	91.44
2003	20.08	29.51	38.26	46.73	53.82	61.32	67.36	72.16	76.15	81.30	86.23	90.85
2004	20.09	29.53	38.17	46.22	54.11	60.55	67.57	73.07	77.33	80.83	85.61	90.22
2005	19.84	29.54	38.20	46.11	53.52	60.88	66.73	73.30	78.31	82.08	85.11	89.56
2006	19.69	29.18	38.20	46.15	53.39	60.21	67.08	72.39	78.56	83.12	86.43	89.04
2007	19.94	28.96	37.75	46.15	53.44	60.07	66.35	72.78	77.58	83.38	87.53	90.42
2008	20.17	29.32	37.46	45.60	53.44	60.12	66.20	71.98	78.00	82.34	87.80	91.57
2009	20.39	29.65	37.93	45.25	52.80	60.13	66.25	71.81	77.14	82.78	86.71	91.86
2010	20.52	29.99	38.36	45.82	52.40	59.40	66.26	71.87	76.96	81.88	87.17	90.71
2011	20.31	30.17	38.79	46.33	53.05	58.95	65.46	71.88	77.02	81.69	86.22	91.20
2012	20.22	29.87	39.02	46.86	53.65	59.69	64.97	71.01	77.03	81.75	86.02	90.20

APPENDIX II - FIGURES

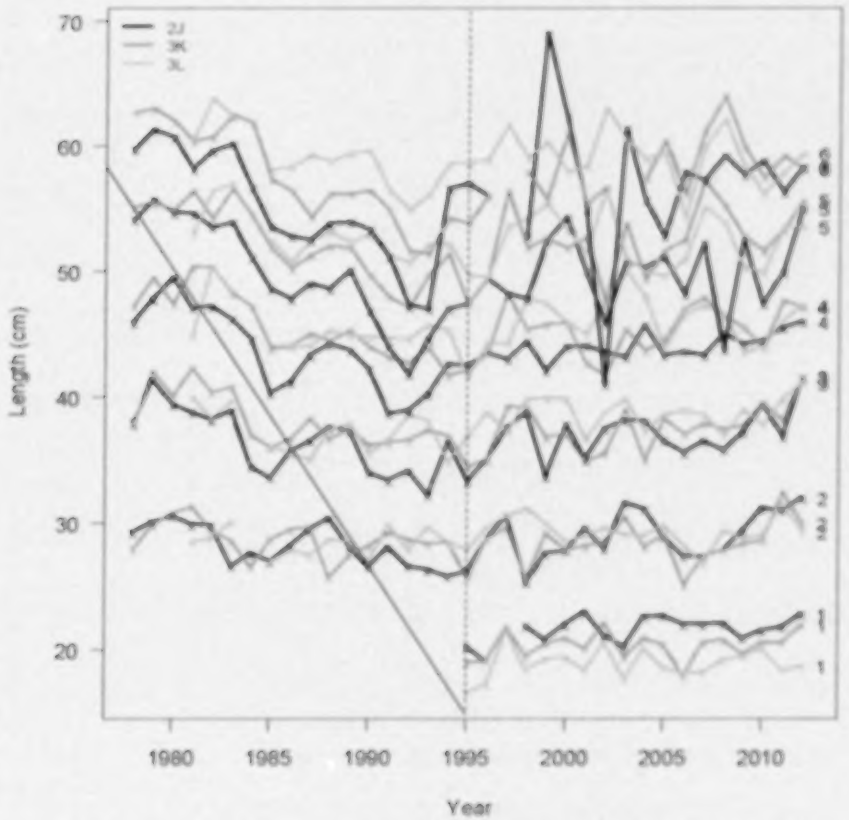

Figure 1. Size at age time-series for Northern cod from the DFO autumn trawl survey. Colors correspond to NAFO Divisions. Ages (1-6) are indicated at the right-hand side.

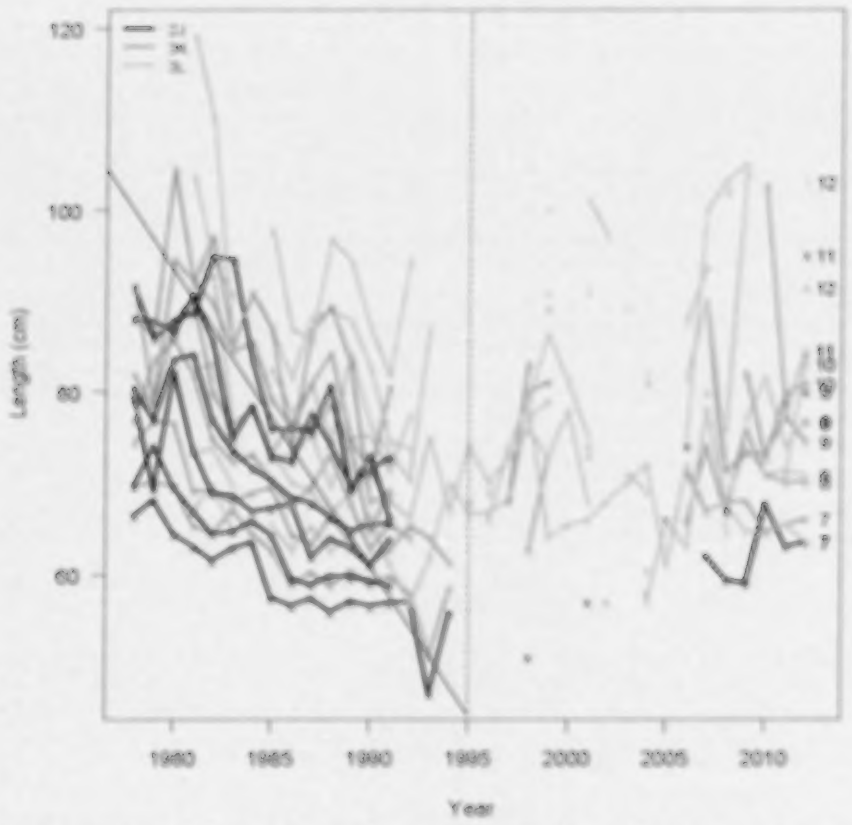

Figure 2. Size at age time-series for Northern cod from the DFO autumn trawl survey. Colors correspond to NAFO Divisions. Ages (7-12) are indicated at the right-hand side.

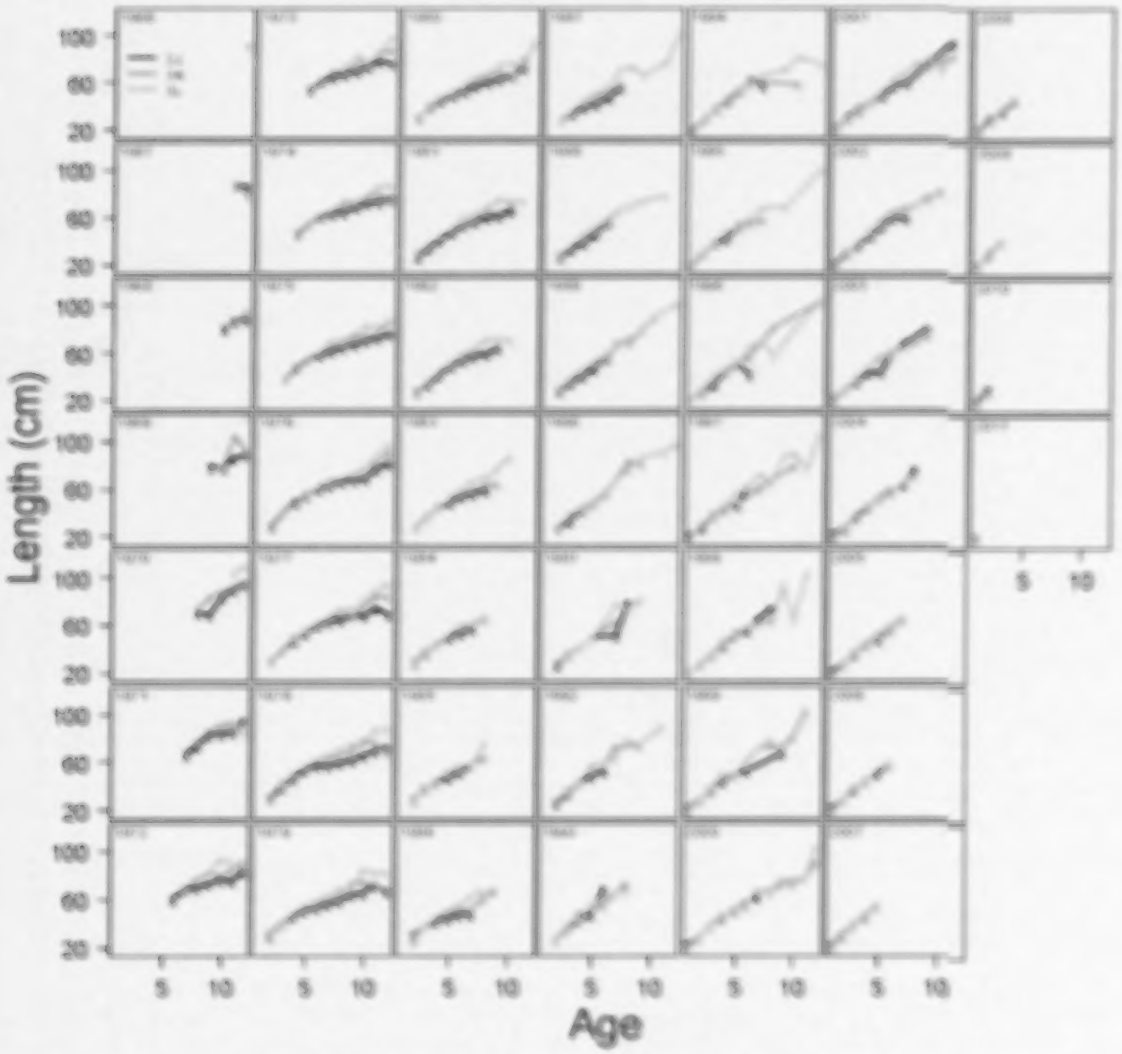

Figure 3. Size-at-age by cohort for Northern cod from the DFO autumn trawl survey. Colors correspond to NAFO Divisions. Cohorts are indicated in the top left-hand corner of each panel.

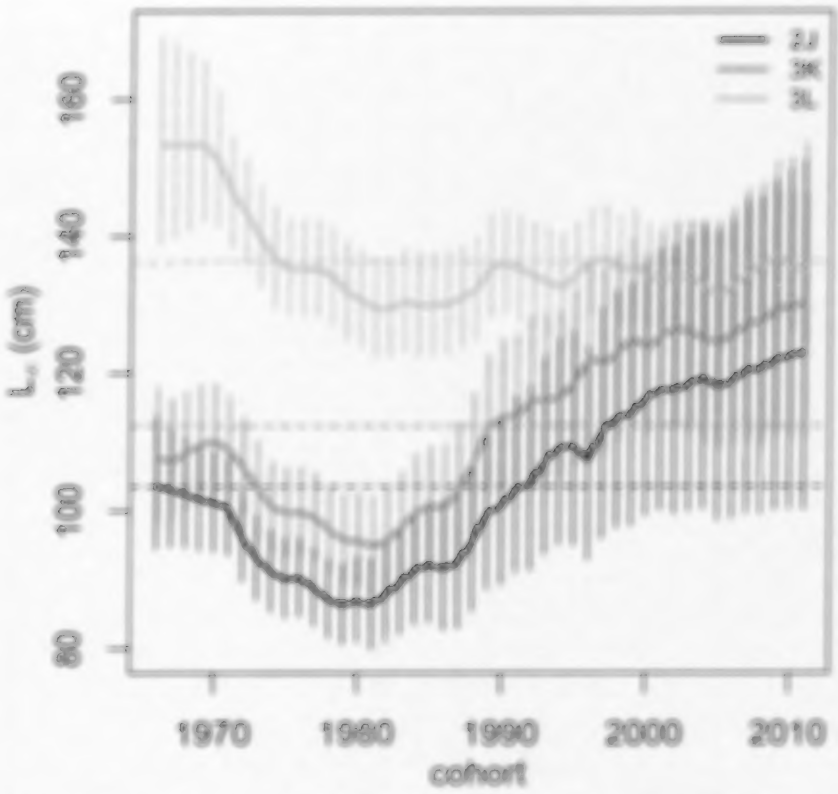

Figure 4. Solid lines connect estimates of the Von Bertalanffy Nond L_∞ parameter for each cohort and NAFO Division. The horizontal dashed lines indicate the series average. Vertical lines indicate 95% confidence intervals. Colors correspond to NAFO Division.

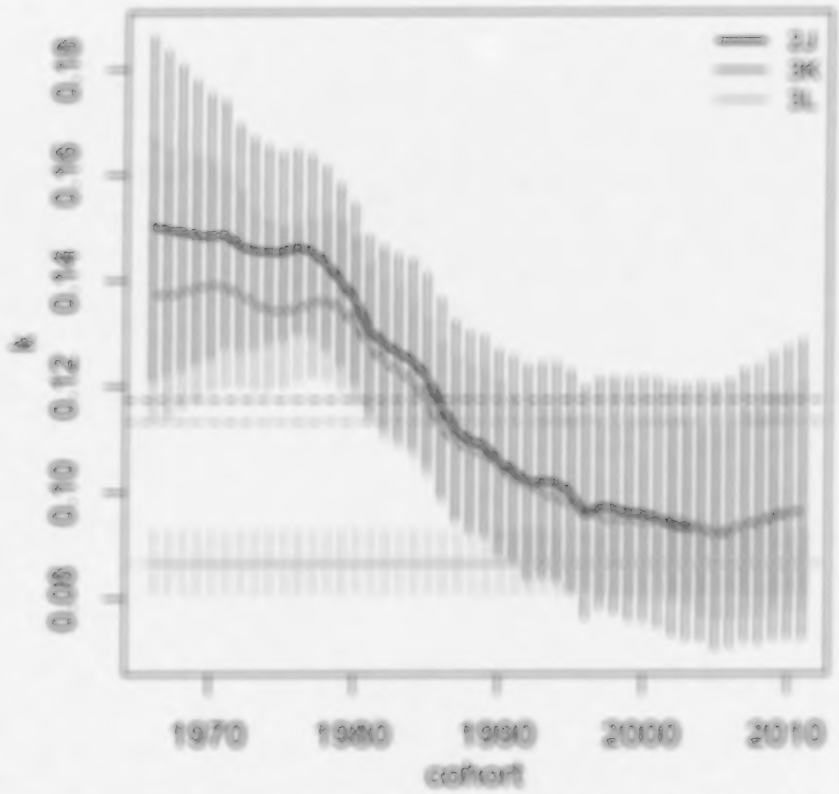

Figure 5. Solid lines connect estimates of the Von Bertalanffy k parameter for each cohort and NAFO Division. The horizontal dashed lines indicate the series average. Vertical lines indicate 95% confidence intervals. Colors correspond to NAFO Division.

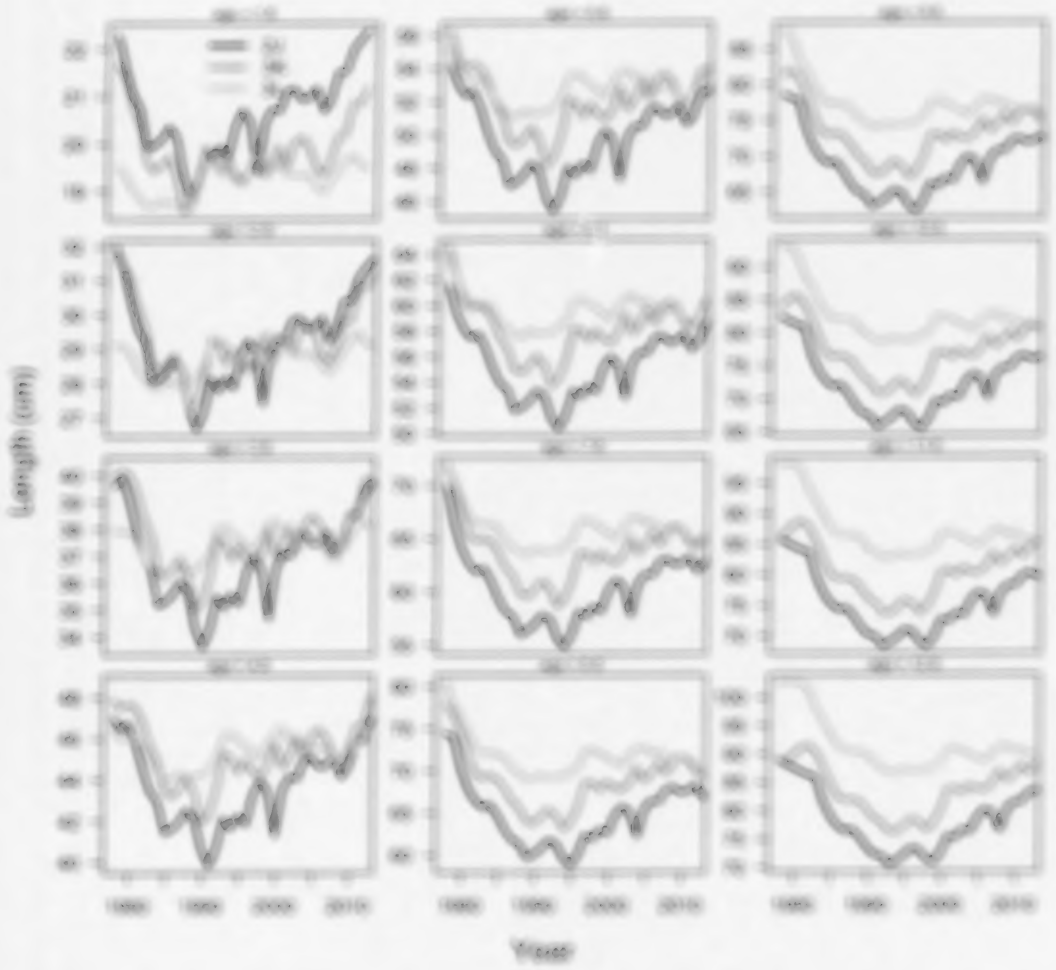

Figure 6. Von Bertalanffy model predicted length-at-age for Nicol in NAFO Divisions 3J, 3K, and 3L. Each panel shows the results for an age class and colors correspond to Divisions. The survey season during the fall and the age at the top of each panel includes the fraction of year.

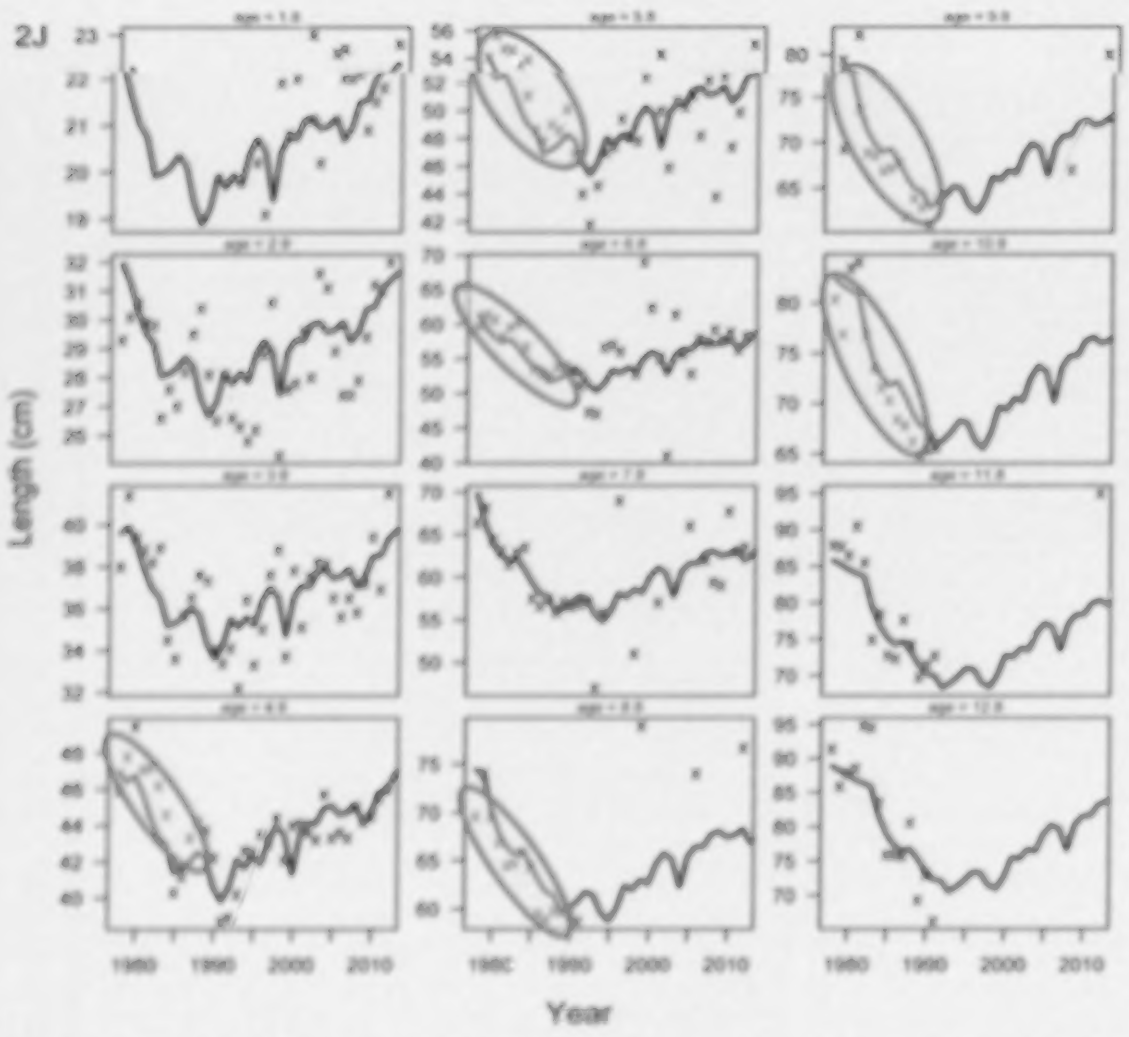

Figure 7. Von Bertalanffy model predicted versus observed length-at-age for Nood in NAFO Division 2J. Each panel shows the results for an age-class. The survey occurs during the fall and the age at the top of each panel includes the fraction of year. Model biases in estimates of length at ages 4-10 during 1978-90 are highlighted.

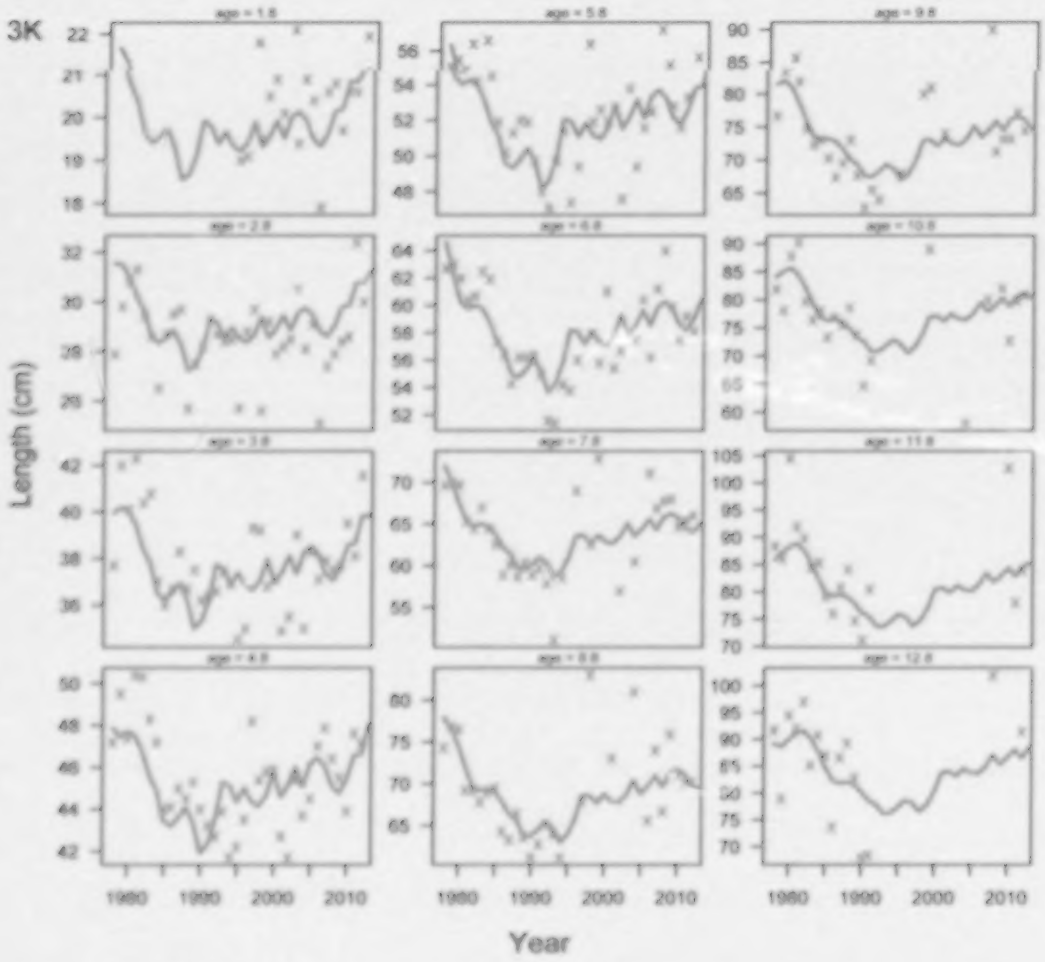

Figure 8. Von Bertalanffy model predicted versus observed length-at-age for Ncod in NAFO Division 3K. Each panel shows the results for an age class. The survey occurs during the fall and the age at the top of each panel includes the fraction of year.

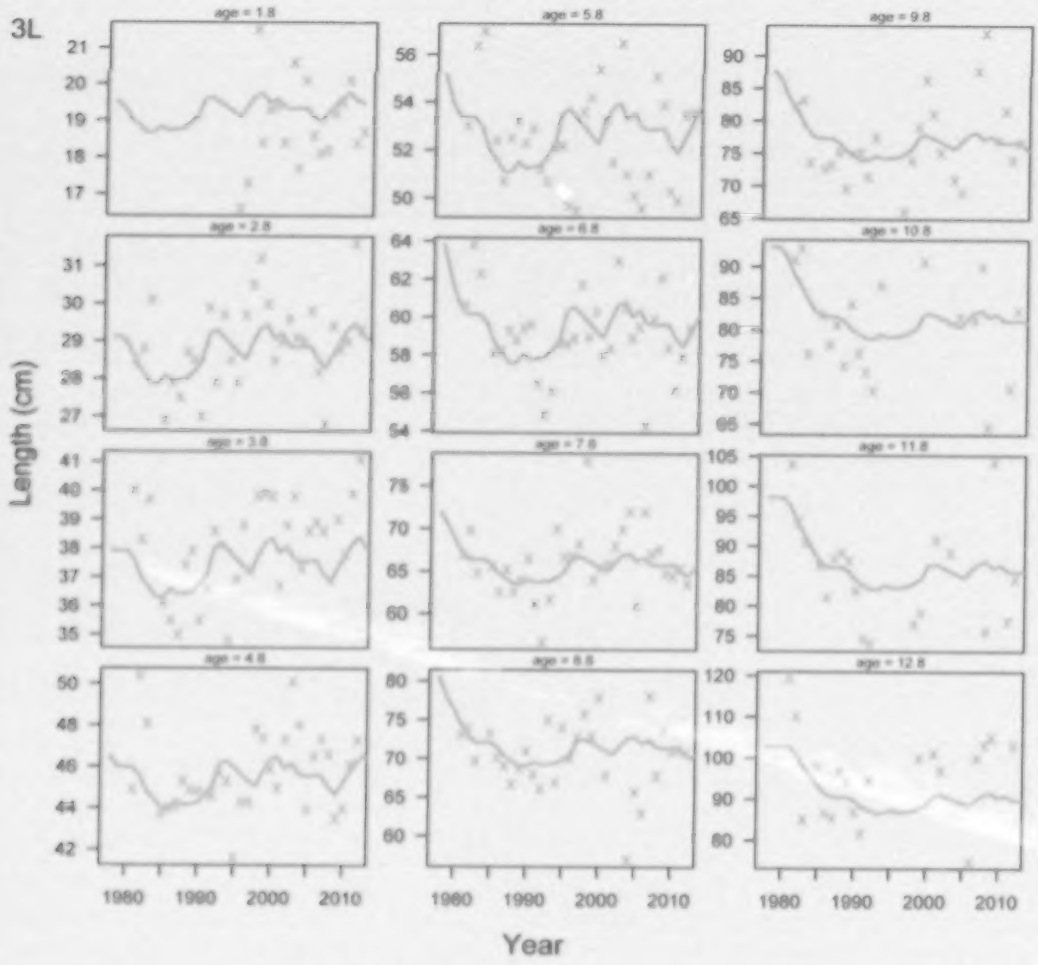

Figure 9. Von Bertalanffy model predicted versus observed length-at-age for Ncod in NAFO Division 3L. Each panel shows the results for an age class. The survey occurs during the fall and the age at the top of each panel includes the fraction of year.

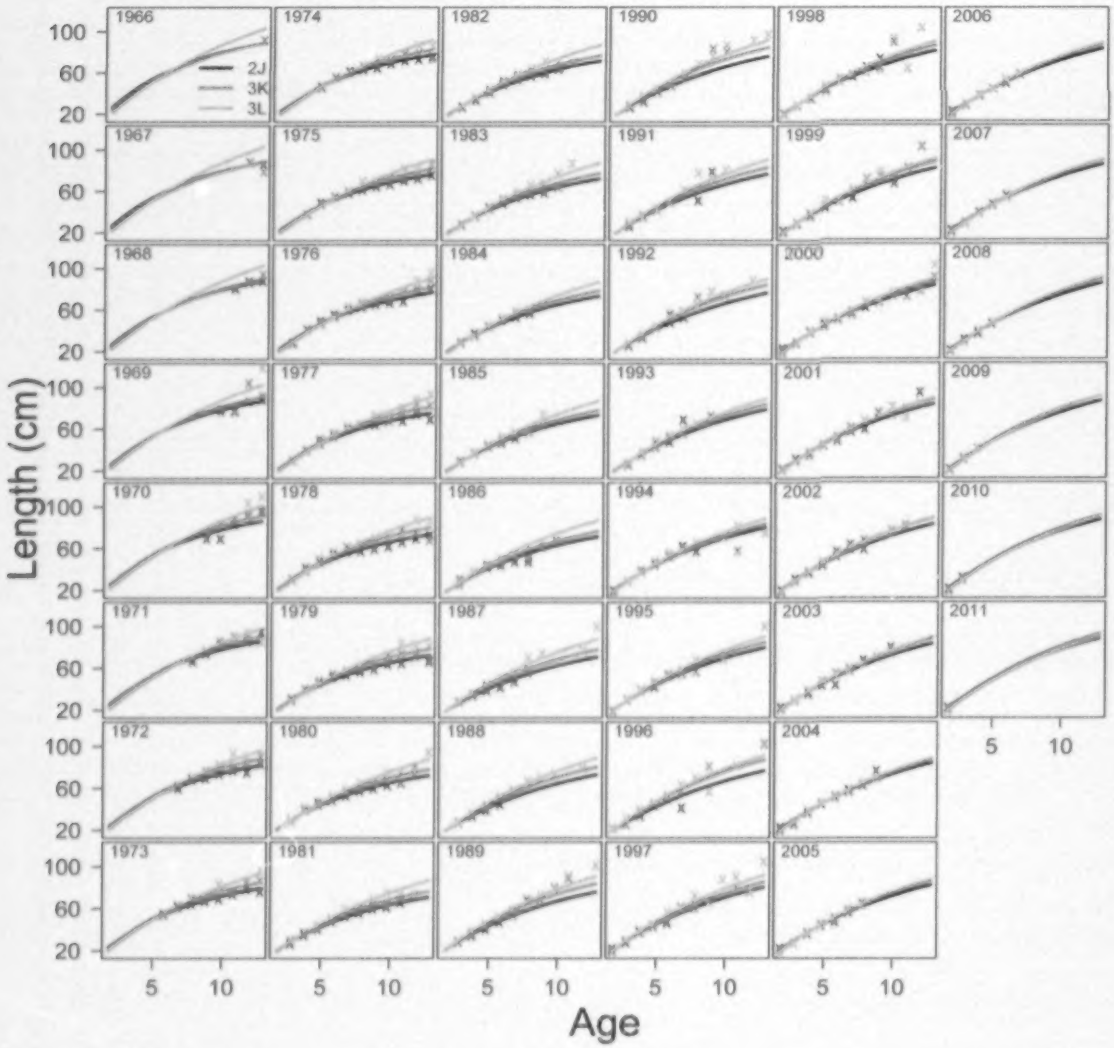

Figure 10. Von Bertalanffy model predicted versus observed weight-at-age for Ncod, by cohort and NAFO Division.

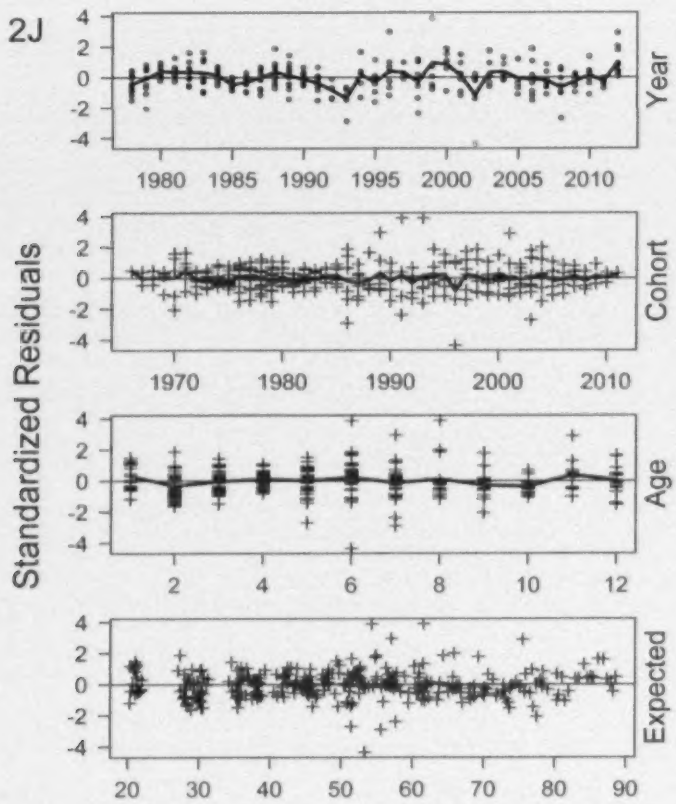

Figure 11. Standardized residuals from fitting the Von Bertalanffy model to Ncod survey average length-at-age in NAFO Division 2J. Panels show residuals versus year, age, cohort, and predicted value. Solid lines in the top three panels indicates the average residual each year, cohort, and age, respectively. Text in the top panel indicates ages that have residual absolute value greater than three.

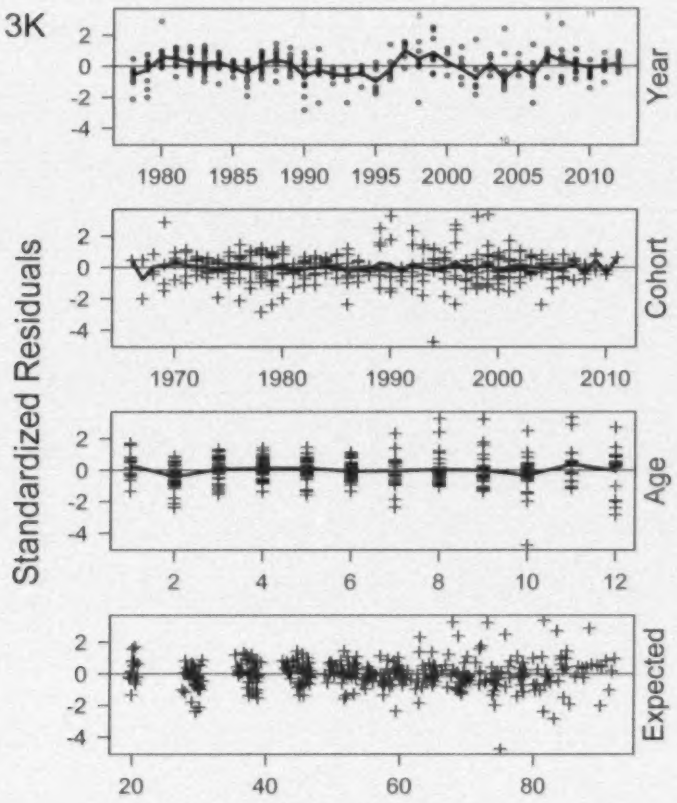

Figure 12. Standardized residuals from fitting the Von Bertalanffy model to Ncod survey average length-at-age in NAFO Division 3K. Panels show residuals versus year, age, cohort, and predicted value. Solid lines in the top three panels indicates the average residual each year, cohort, and age, respectively. Text in the top panel indicates ages that have residual absolute value greater than three.

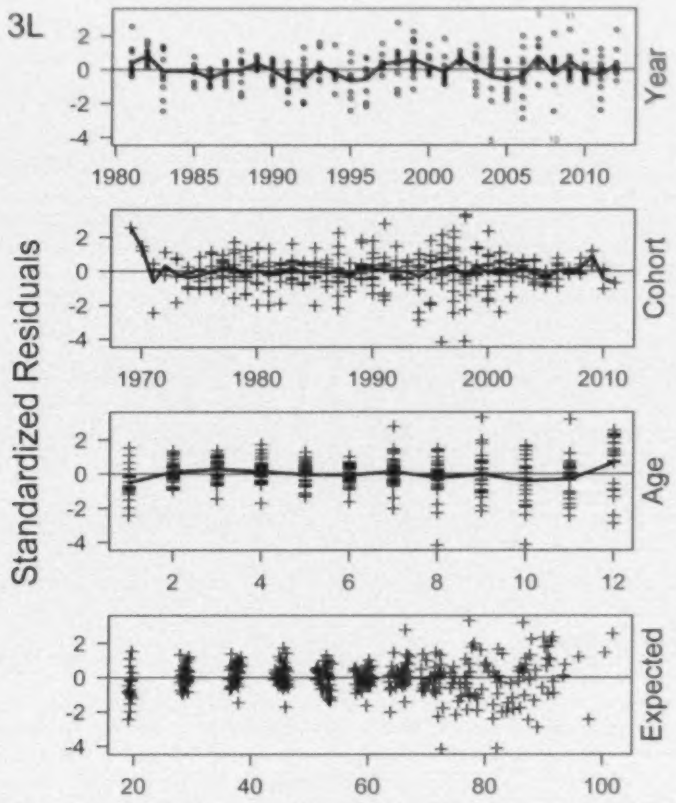

Figure 13. Standardized residuals from fitting the Von Bertalanffy model to Ncod survey average length-at-age in NAFO Division 3L. Panels show residuals versus year, age, cohort, and predicted value. Solid lines in the top three panels indicates the average residual each year, cohort, and age, respectively. Text in the top panel indicates ages that have residual absolute value greater than three.

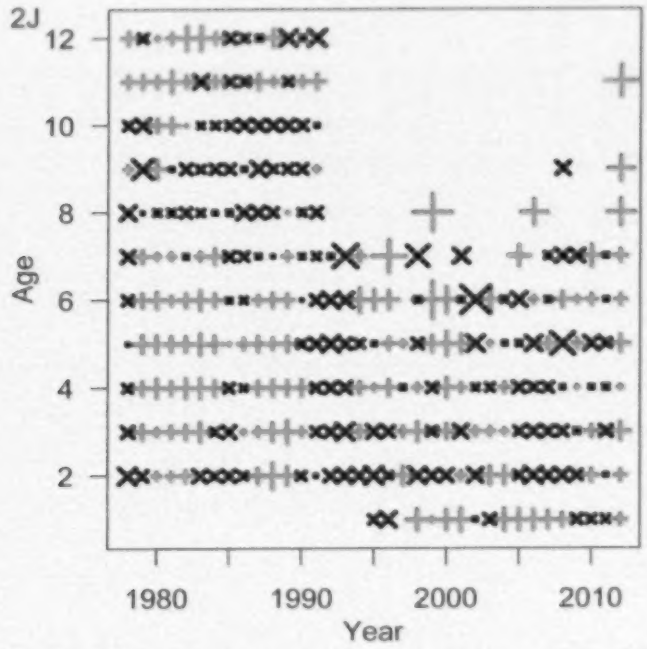

Figure 14. Matrix plot of NAFO Division 2J residuals from the Von Bertalanffy model. Red +'s are positive and black ×'s are negative. The sizes of plotting symbols are proportional to the absolute value of the residuals. Blanks indicate ages and years with no sampled lengths or too few (in a cohort) to fit the model.

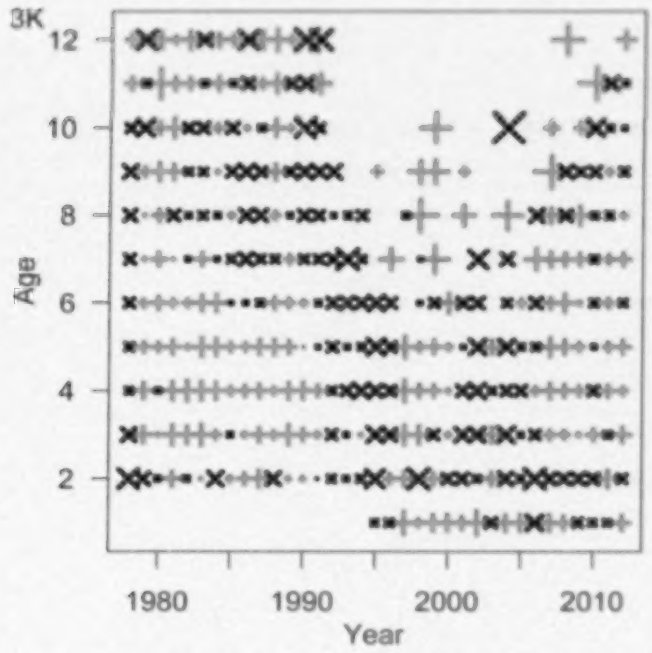

Figure 15. Matrix plot of NAFO Division 3K residuals from the Von Bertalanffy model. Red +'s are positive and black ×'s are negative. The sizes of plotting symbols are proportional to the absolute value of the residuals. Blanks indicate ages and years with no sampled lengths or too few (in a cohort) to fit the model.

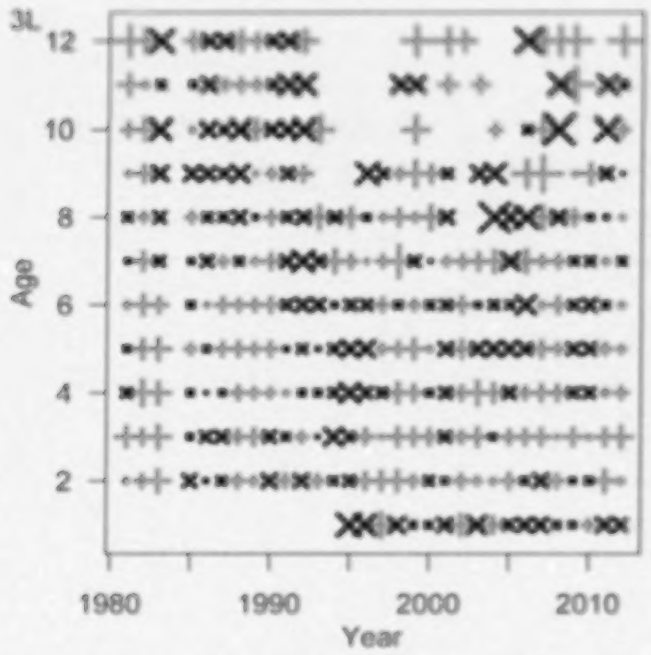

Figure 18. Matrix plot of NAFO Division 3L residuals from the Von Bertalanffy model. Red +'s are positive and black ×'s are negative. The sizes of plotting symbols are proportional to the absolute value of the residuals. Blanks indicate ages and years with no sampled lengths or too few (in a cohort) to fit the model.

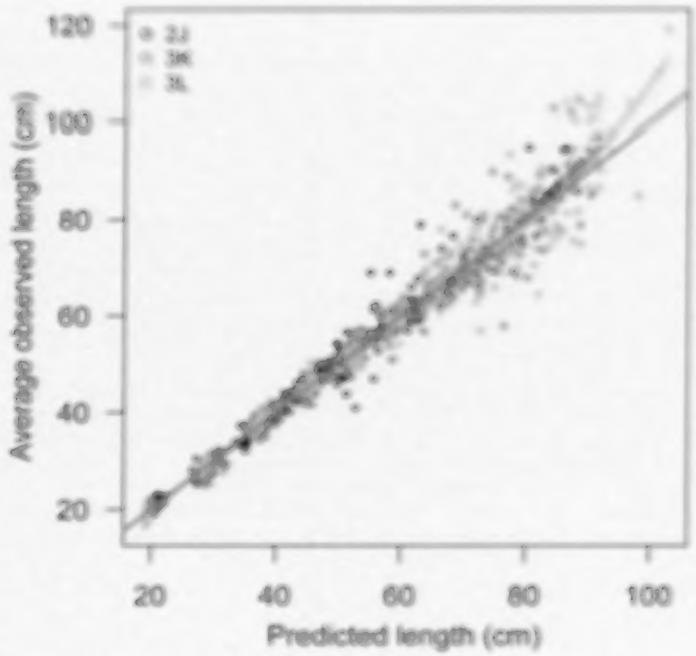

Figure 17. Von Bertalanffy model predicted versus observed lengths for all ages and years. Colors correspond to NAFO Divisions. Lines indicate a loess smooth of observed versus predicted lengths, and the 1:1 line is in grey.

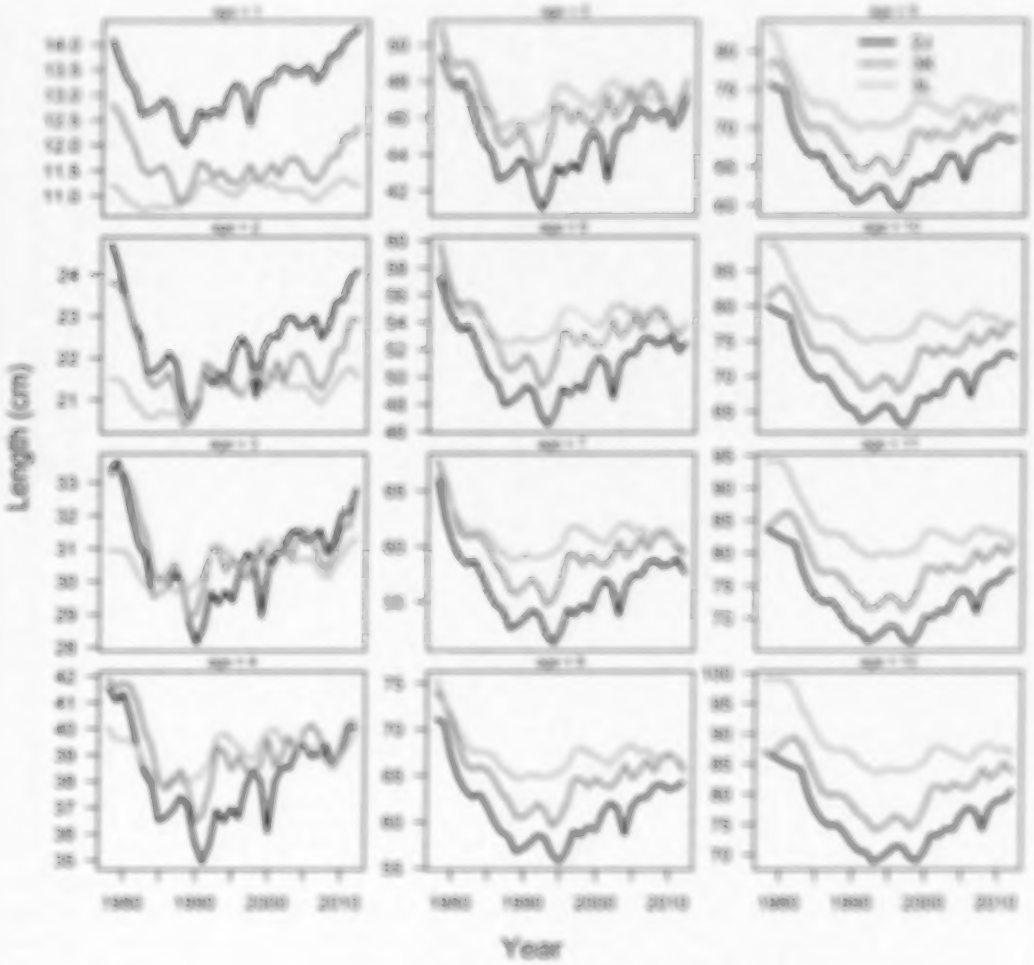

Figure 18. Von Bertalanffy model predicted beginning-of-year length-at-age for Nicod in NAFO Divisions 2J, 3K, and 3L. Each panel shows the results for an age class and colors correspond to Divisions.

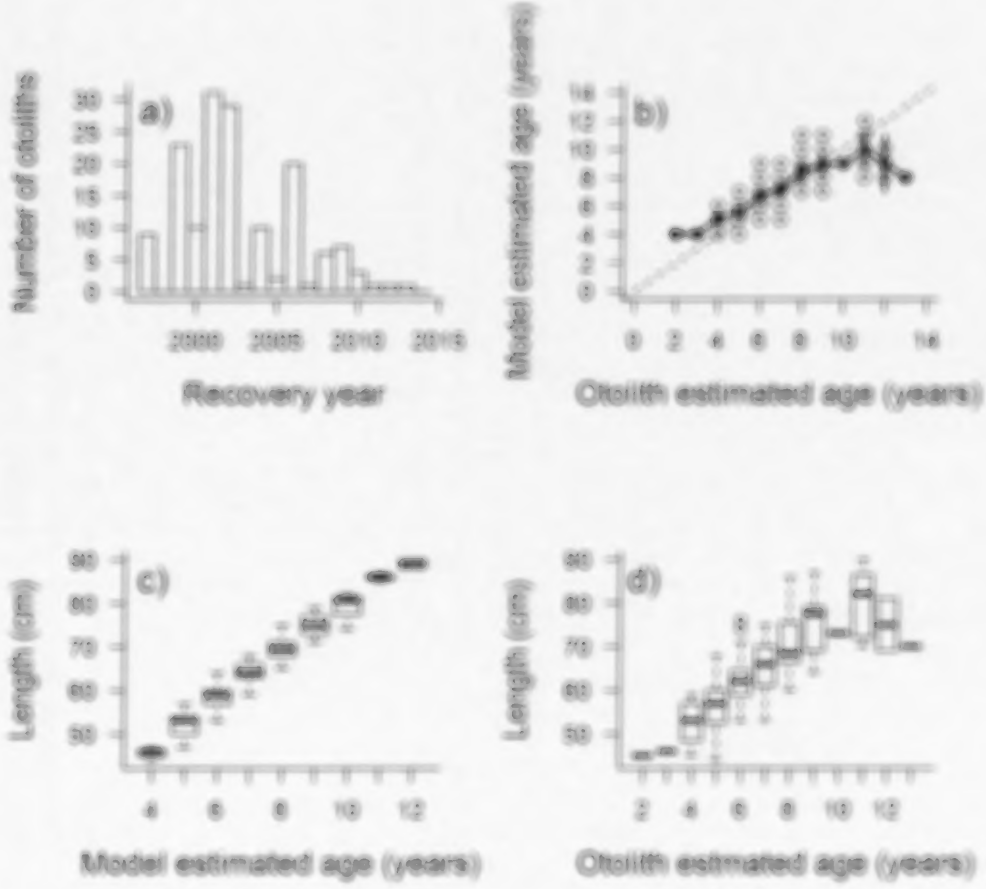

Figure 19. Aged otolith recovery from tagged fish. Panel (a): The number of otoliths recovered by year from the Northern cod stock. Only recoveries from 2J, 3K and 3L were included. Panel (b): Estimated age based on the VonB model versus measured (i.e. real[1]) age based on otoliths. The dashed 1:1 line represents a perfect fit. The thick black line is the mean model estimated age at a given otolith measured age with 95% confidence intervals calculated for the age bins where more than one otolith has been recovered (i.e. all age classes but 2, 3, 13, 14). Panel (c): Length variation within model estimated age bins and Panel (d) otolith measured (i.e. real[1]) age bins (d).